SEWAGE AND INDUSTRIAL WASTES

JOURNAL of the FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

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Operator's Corner

Outfall Cleaning, Operator Training

NOVEMBER 1958—VOL. 30, No. 11

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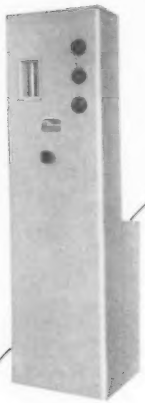

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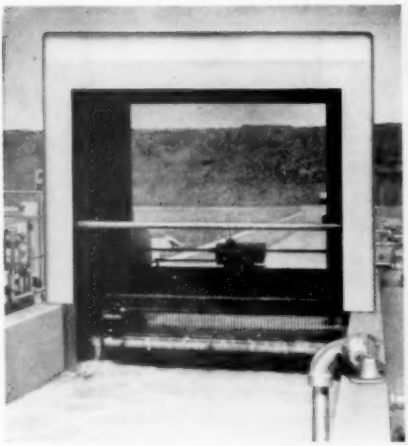

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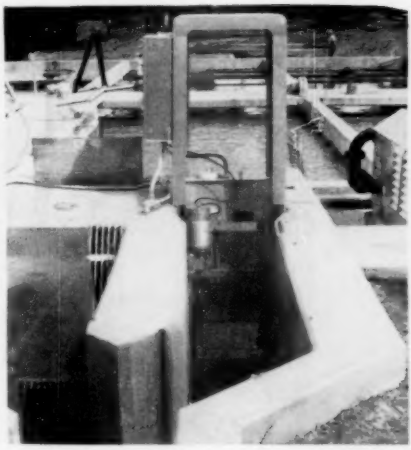

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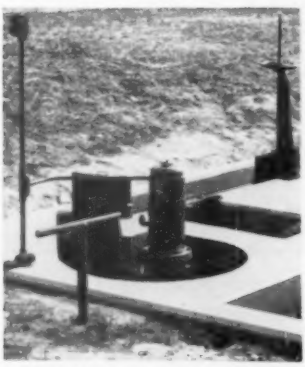

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A monthly Journal devoted to the advancement of fundamental and practical knowledge concerning the nature, collection, treatment and disposal of sewage and industrial wastes, and the design, construction, operation and management of such works. The Journal was known as *Sewage Works Journal* until January 1950.

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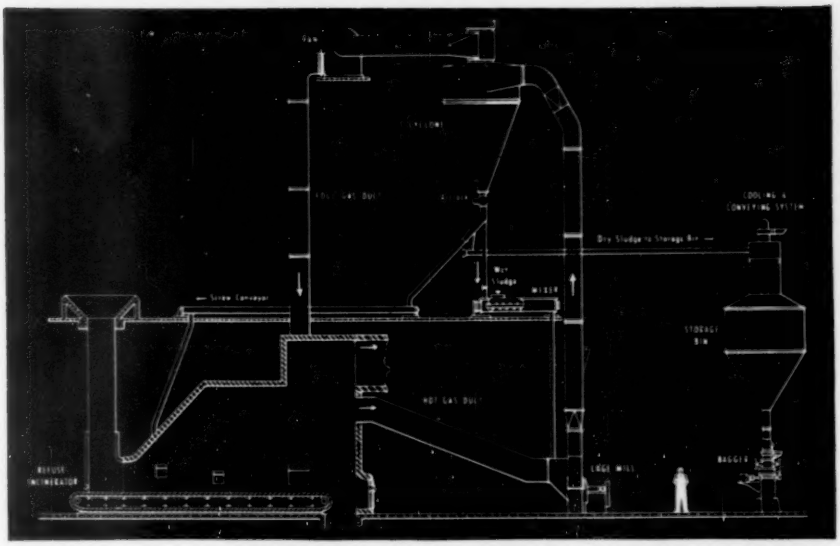

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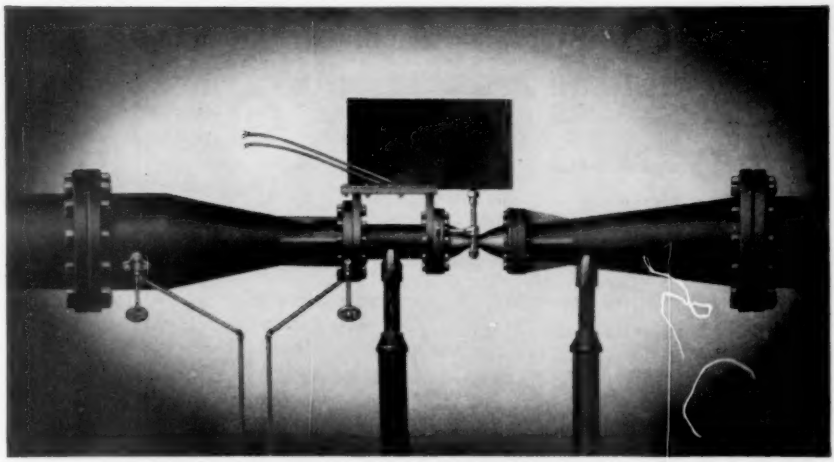

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Association	*Place*	*Time*
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New England Sewage and Industrial Wastes Assn.	Statler Hilton Hotel Hartford, Conn.	Nov. 5–6, 1958
Nebraska Sewage and Industrial Wastes Assn.	Lincoln Hotel Lincoln, Nebr.	Nov. 6–7, 1958
North Carolina Sewage and Industrial Waste Assn.	Hotel O'Henry Greensboro, N. C.	Nov. 10–12, 1958
South Carolina Water and Sewage Works Assn.	Jefferson Hotel Columbia, N. C.	Nov. 14, 1958
Oklahoma Water, Sewage and Industrial Conf. (Short Course)	Okla. State Univ. Stillwater, Okla.	Nov. 17–21, 1958
New York Sewage and Industrial Wastes Assn.	Park Sheraton Hotel New York, N. Y.	Jan. 22–23, 1959
Texas Water and Sewage Works Assn.	Texas A & M College College Station, Tex.	Mar. 1–6, 1959
Mississippi Sewage and Industrial Wastes Assn.	Robert E. Lee Hotel Jackson, Miss.	Mar. 6, 1959
New Jersey Sewage and Industrial Wastes Assn.	Traymore Hotel Atlantic City, N. J.	Mar. 11–13, 1959
Louisiana Conf. on Water Supply and Sewerage	Louisiana State Univ. Baton Rouge, La.	Mar. 18–20, 1959

THIRTY-SECOND ANNUAL MEETING

Federation of Sewage and Industrial Wastes Associations
Host—Sewage and Industrial Wastes Section,
Texas Water and Sewage Works Association
Statler Hilton Hotel, Dallas, Texas
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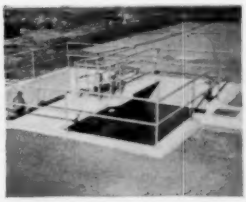

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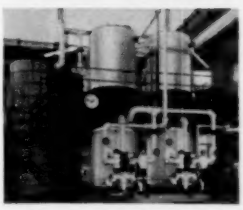

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Bulletin 1960

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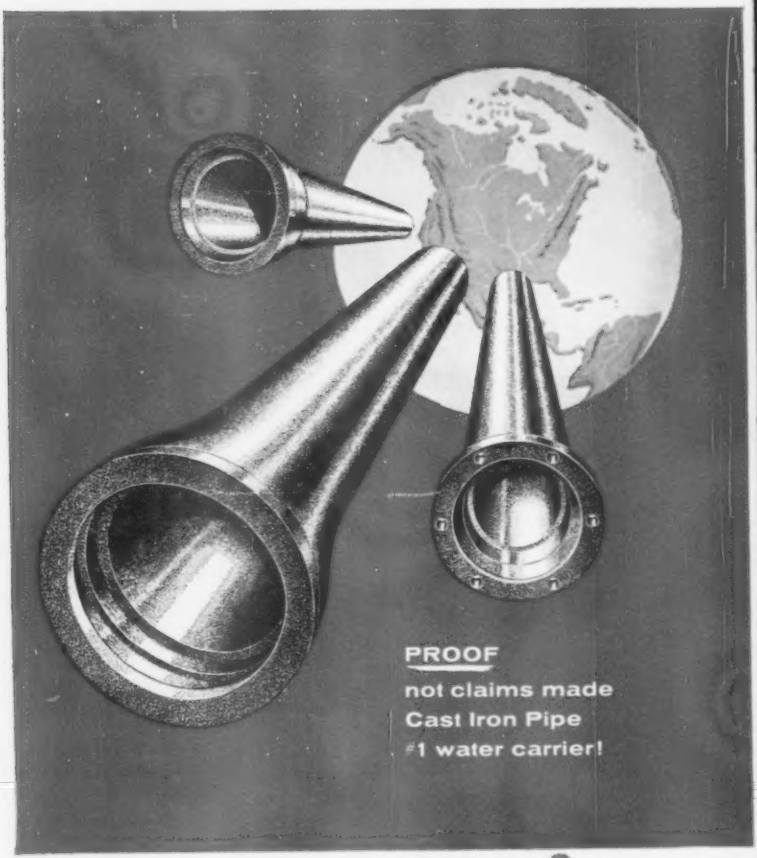

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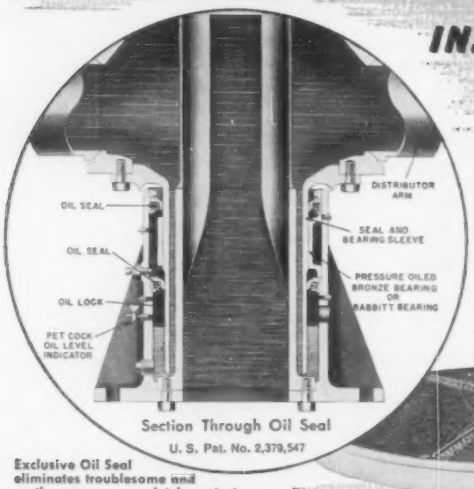

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Hundreds of installations have proved the advantages of *American* Rotary Distributors. This approval by consulting engineers is based on economy of initial cost, structural strength and durability, superior liquid distribution, applicability to wide ranges of flow and available head, and minimum maintenance. Inherent design features reduce hydraulic-head losses to a minimum, and provide for maximum utilization of available hydraulic head in performance of useful work. *Every oil seal unit installed has given excellent, trouble-free service!* Available in a wide range of both Reaction-Drive and Motor-Driven Positive-Drive Distributors to meet all variations of actual field conditions—for rapid or standard rate waste filters, sand filters, or for water aeration. *Utilize the experience of American engineers.*

For helpful data and design details, write for Technical Supplement RD

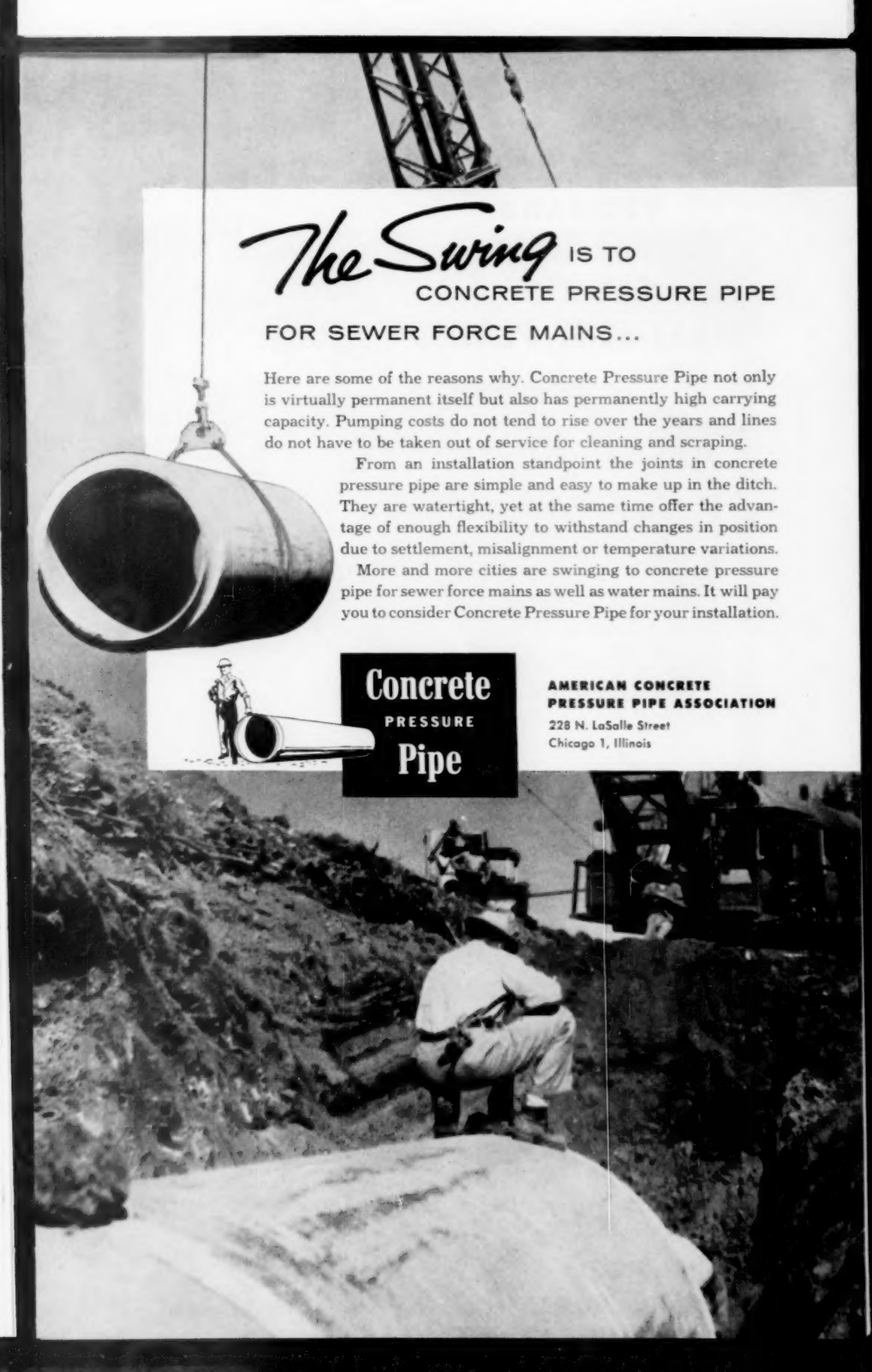
A Complete Line of Pumps and Process Equipment for Sewage and Industrial Waste Treatment.

AMERICAN WELL WORKS

IN OUR 50TH YEAR
110 North Broadway
AURORA, ILLINOIS

Pumping, Sewage Treatment, and Water Purification Equipment
RESEARCH · ENGINEERING · MANUFACTURING

Offices: Chicago · New York · Cleveland · Cincinnati · Kansas City · Sales Representatives throughout the World



The Swing IS TO CONCRETE PRESSURE PIPE FOR SEWER FORCE MAINS...

Here are some of the reasons why. Concrete Pressure Pipe not only is virtually permanent itself but also has permanently high carrying capacity. Pumping costs do not tend to rise over the years and lines do not have to be taken out of service for cleaning and scraping.

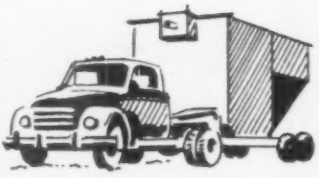
From an installation standpoint the joints in concrete pressure pipe are simple and easy to make up in the ditch. They are watertight, yet at the same time offer the advantage of enough flexibility to withstand changes in position due to settlement, misalignment or temperature variations.

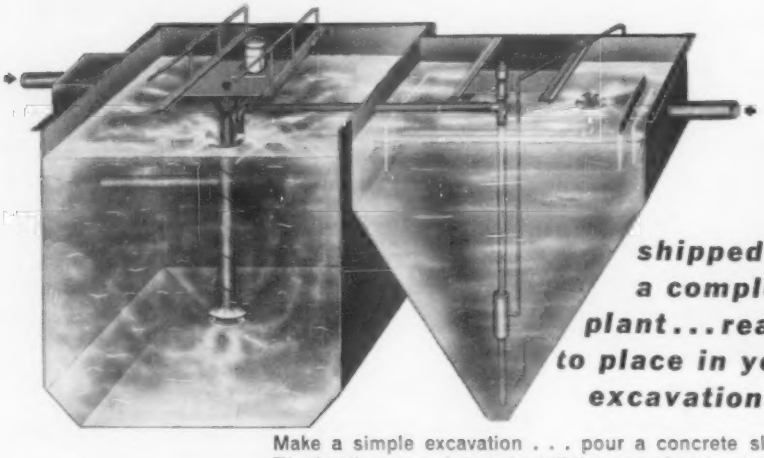
More and more cities are swinging to concrete pressure pipe for sewer force mains as well as water mains. It will pay you to consider Concrete Pressure Pipe for your installation.

Concrete PRESSURE Pipe

AMERICAN CONCRETE PRESSURE PIPE ASSOCIATION
228 N. LaSalle Street
Chicago 1, Illinois

YEOMANS PREFABRICATED SEWAGE TREATMENT PLANTS





shipped as a complete plant... ready to place in your excavation!

Make a simple excavation . . . pour a concrete slab. That's all you need do to install this complete treatment plant. And, because these Yeomans plants are standardized, your sewage treatment dollar goes farther. Fast delivery and quick start-up of the plants keep construction schedules flexible, too.

Yeomans "package" plants are built around the well-known Cavitator® which treats sewage by the high-efficiency Aerobic Digestion process. The effluent (discharge) is odorless and clear. There are no blowers, compressors, nozzles, or diffusion tubes to be maintained. Standard systems are supplied in capacities from 2000 to 7500 gallons per day. A factory-trained engineer is available to supervise installation, train operators, and test performance.

Your investment is safe in a Yeomans sewage treatment plant. Each one incorporates 50 years' experience in handling sewage. Each is fully approved by health and building authorities. Why not write for details now.

ECONOMICAL SEWAGE TREATMENT FOR:

Schools
Hospitals
Subdivisions
Drive-in Theatres
Motels
Resorts
Restaurants
Trailer Courts
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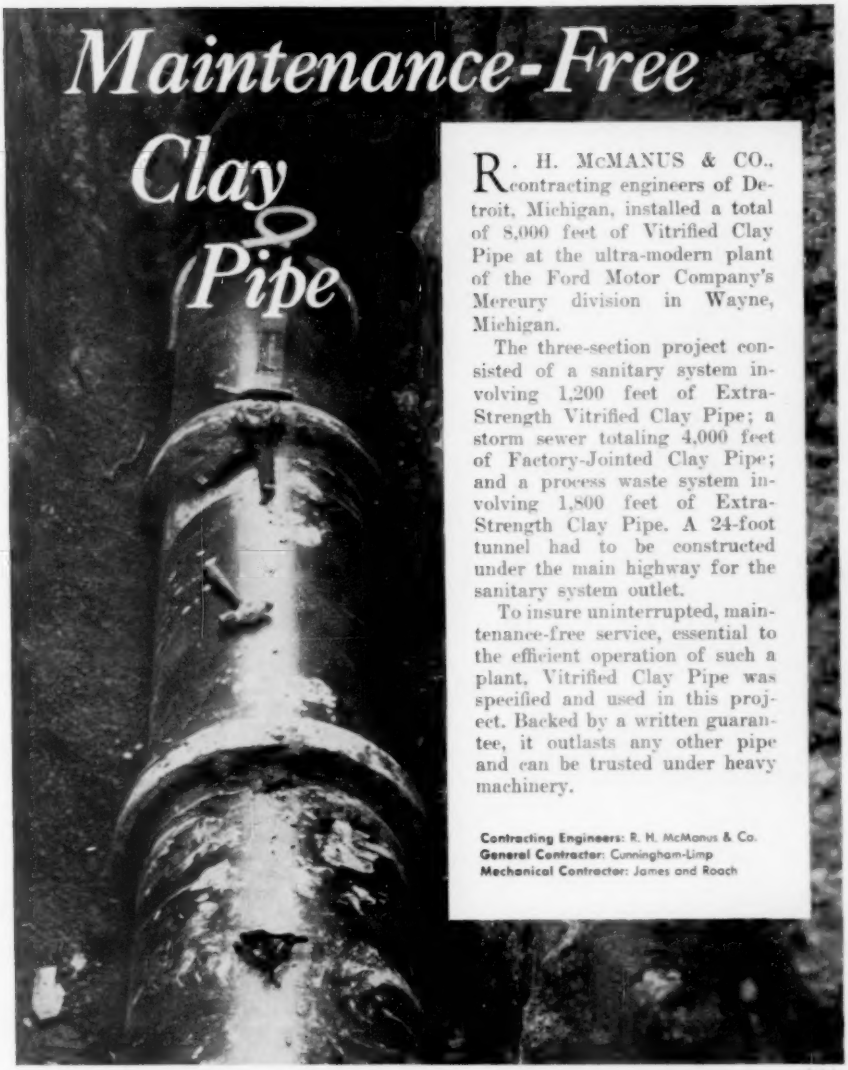
T-5802

Send for Bulletin No. 101 on Prefabricated Sewage Treatment Plants

YEOMANS

1999-7 North Ruby Street • Melrose Park, Illinois

YOUR MOST COMPLETE LINE OF SEWAGE TREATMENT EQUIPMENT



R. H. McMANUS & CO., contracting engineers of Detroit, Michigan, installed a total of 8,000 feet of Vitrified Clay Pipe at the ultra-modern plant of the Ford Motor Company's Mercury division in Wayne, Michigan.

The three-section project consisted of a sanitary system involving 1,200 feet of Extra-Strength Vitrified Clay Pipe; a storm sewer totaling 4,000 feet of Factory-Jointed Clay Pipe; and a process waste system involving 1,800 feet of Extra-Strength Clay Pipe. A 24-foot tunnel had to be constructed under the main highway for the sanitary system outlet.

To insure uninterrupted, maintenance-free service, essential to the efficient operation of such a plant, Vitrified Clay Pipe was specified and used in this project. Backed by a written guarantee, it outlasts any other pipe and can be trusted under heavy machinery.

Contracting Engineers: R. H. McManus & Co.
General Contractor: Cunningham-Limp
Mechanical Contractor: James and Roach

C-1043

NATIONAL CLAY PIPE MANUFACTURERS, INC.

1820 N Street, N. W., Washington, 6, D. C.

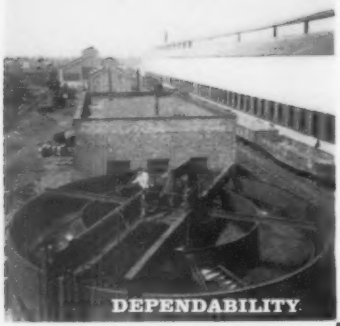
311 High Long Bldg., 5 E. Long St., Columbus 15, Ohio • 703 Ninth & Hill Bldg., Los Angeles 15, California

Box 172, Barrington, Illinois • 206 Mark Bldg., Atlanta 3, Georgia

SAVINGS

SIMPLICITY

IN WASTE TREATMENT FOR EVERY INDUSTRY



DEPENDABILITY

GRAVER Offers

SAVINGS • SIMPLICITY • DEPENDABILITY

SAVINGS in a tissue mill. Over $7,000 a month saved on recovered pulp fiber and recovered water. White water treatment uses Graver flotation equipment.

SIMPLICITY in a missile plant. Plating of missile parts requires over 10 processes resulting in chrome, cyanide, acid and alkali wastes. These wastes are collected from 120 plating tanks into three streams and treated by an integrated Graver plant providing for destruction and reduction of wastes. Central control board, simple operating charts keep operator time to a minimum.

DEPENDABILITY in a steel plant. Specially designed clarifier, installed in 1944 effectively treats flotable and settleable material in oily wastes from steel production. Unit meets all requirements of plant as it has done since the time it was installed 14 years ago.

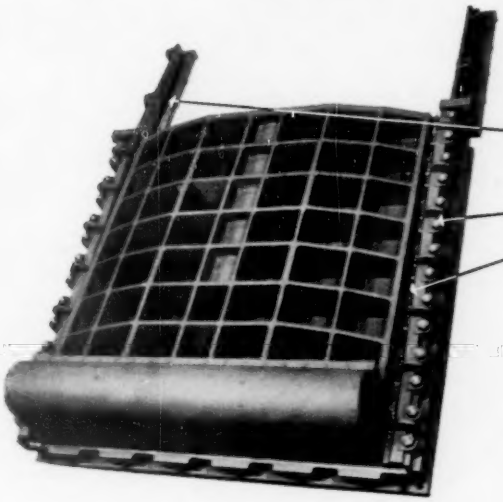
Your waste treatment plant can incorporate all three advantages. Perhaps no recovery is possible or desirable at your plant, yet you still get simplicity and dependability and save because of them through low requirements on equipment, time, labor and maintenance. Perhaps automatic operation is not indicated, yet with Graver you still get the simplest operating plant possible plus the other advantages. Graver offers equipment for all types of waste treatment in a wide range of industries. Our experience and the high quality design and construction of our units assure the most advantages in your waste treatment plant.

Request literature! Tell us the industry you are interested in or the problem you have, and we will send you case history studies of how problems were solved and how individual plants, representative of many, benefited from Graver's trio of advantages – savings, simplicity and dependability.

GRAVER

Industrial Waste Treatment Dept. W-522
GRAVER WATER CONDITIONING CO.
Division of Union Tank Car Company
216 West 14th Street, New York 11, N. Y.

2,300 pounds of Everdur used in new 8-ton cast-iron sluice gate



1 ¾" x 3" Everdur facing strips for gate leaf and frame.

2 1½" Everdur bolts and nuts.

3 Everdur adjusting bolts for cast-bronze wedges.

More than a ton of Everdur was used for facing strips and fastenings in this 8' x 8' sluice gate leaf and frame assembly designed and furnished by the Coldwell-Wilcox Division of Krajewski-Pesant Mfg. Corp., New York City. Consulting engineers, Gannett Fleming Corddry & Carpenter, Inc., Harrisburg, Pa.

This direct-pressure type sluice gate is one of two recently installed by Empresa de Energia Electrica at the Quebradona Dam in Columbia, South America, to regulate the flow of potable water to the city of Medellin.

The 100-foot head of water behind the dam exerts 450,000 pounds pressure on each 8 x 8-foot gate. Everdur* (copper-silicon alloy) was selected to seal against this load because of its high strength and corrosion resistance—plus ready workability and weldability. Sewage treatment and water works equipment of Everdur has been in service without replacement for a quarter century and longer.

Write for Publication E-11, "Everdur Copper-Silicon Alloys for Sewage Treatment and Waterworks Equipment"—or for technical help in selecting the correct material for your job. Address: The American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Limited, New Toronto, Ont.

*Reg. U.S. Pat. Off. 57133

EVERDUR Anaconda's Family of Copper-Silicon Alloys
MADE BY THE AMERICAN BRASS COMPANY
STRONG · WORKABLE · WELDABLE · CORROSION-RESISTANT

How to help prevent this in your COMMUNITY!

New HAYS dissolved oxygen meter gives instantaneous and continuous record of dissolved oxygen content of effluent from sewage treatment and industrial plants

Maintenance of adequate DO (dissolved oxygen) in streams containing fish or other marine life is today one of the principal problems facing Sewage Treatment and Industrial plants whose effluent is fed into such streams.

All too often, in communities across the nation, scenes like the above have occurred . . . with subsequent investigations finding insufficient dissolved oxygen as the probable cause.

One of the principal difficulties in preventing this situation has been the absence of a reliable method of determining dissolved oxygen content of effluent accurately, quickly and continuously. Until now, most operators have been forced to use only occasional "spot check" methods which were of questionable value due to length of time required to perform the tests and because of varying operator techniques.

Continuous DO analysis now possible

To alleviate this pressing problem, Hays now offers a significant new instrument which should be a part of the basic equip-

ment of every sewage treatment plant and affected industrial plant in the United States. This unit can be very simply installed. It gives the operator a constant 24 hour check and record of the dissolved oxygen content of the water in percent saturation measured at the point where the effluent leaves the plant to join the stream. A sample chart showing such a record for the effluent from the sewage treatment plant of a prominent mid-western community is shown below.

Basic operating principles—"Henry's Law"

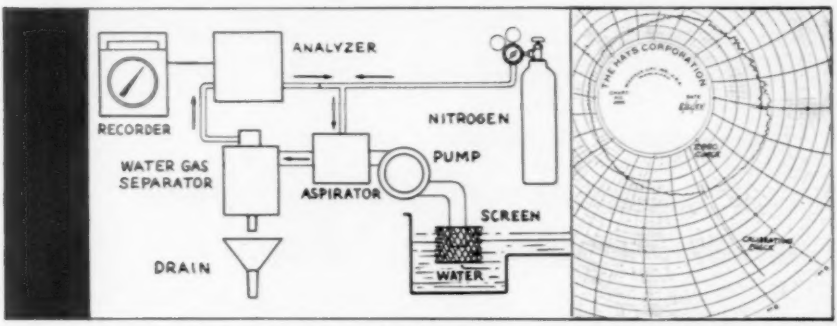
The operation of the system is indicated in the schematic diagram below. The scientific basis of operation may be found in Henry's Law which states essentially: "The amount of Oxygen dissolved in water is directly proportional to the partial pressure of the oxygen above the water surface."

A continuous sample of water to be analyzed is pumped through the aspirator. Suction developed here produces a rapid circulation of gas through the system. A minute quantity of nitrogen added at this point maintains system pressure above atmosphere. At the separator, water passes to drain while the gas is directed to the analyzer. Here the oxygen content of the gas is analyzed in percent by volume, results being indicated on a standard recorder calibrated to read directly in percent saturation.

Proven equipment

Hays brings to the solution of this problem a long and outstanding record in gas analysis. Hays Oxygen Recorders, the primary component of this new Dissolved Oxygen Meter, have long been recognized as the outstanding industrial instrument for this purpose. Thousands of them are in use in leading chemical companies, steel mills, power plants and other industries where oxygen analysis has long been a vital consideration. In over twelve years of usage they have built up an enviable reputation for dependable, accurate, trouble-free operation.

For more information on this significant new development just mail the coupon below.



Schematic diagram of Hays Dissolved Oxygen Meter. One conveniently located recorder provides an instantaneous and continuous record of oxygen content of surface waters.

Chart Showing dissolved oxygen content of effluent from sewage plant of a midwestern city as determined by Hays oxygen meter. Chart provides permanent 24 hour record of dissolved oxygen content.

Automatic Combustion Control
Boiler Panels • CO₂ Recorders
Variflow Meters and Varitrol
Gas Analyzers • Draft Gages
Combustion Test Sets
Electronic Oxygen Recorders
Electronic Flowmeters
Electronic Feed Water Controls
Miniature Remote Indicators

THE hays CORPORATION

MICHIGAN CITY, INDIANA

Hays Corporation
Michigan City 48, Indiana

Gentlemen:

Please forward detailed information on your new dissolved oxygen meter.

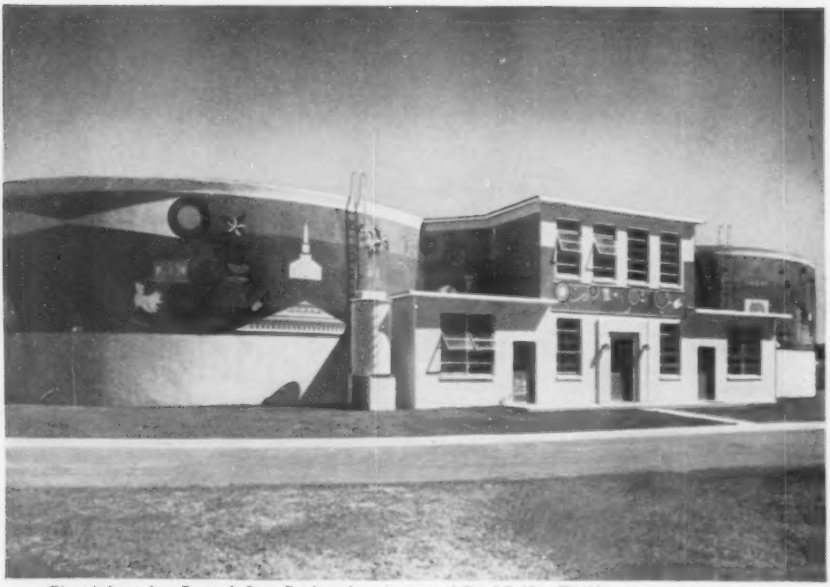
Name_____

Title_____

Organization_____

Street_____

City_____ State_____



Plant is located on Ponce de Leon Boulevard, main street of Coral Gables, Florida. Walls are decorated with historic scenes done by famous artist John St. John.

In Coral Gables, Florida . . .

modern concrete made this sewage treatment plant a good neighbor

A handsome addition to the city, this plant will cause no loss in property values.

More and more communities like Coral Gables, Florida, are handling the construction of sewage disposal plants the modern way: by building a well-designed, odor-free treatment plant of modern concrete that can be a credit to the community wherever it's located.

Concrete used this way can be beautiful as well as practical. In Coral Gables, the sewage treatment plant is almost a civic show place.

Construction costs with concrete are moderate—and upkeep expense is always low. This is one material that can't rust, rot or burn. It lasts a lifetime. When America builds for beauty . . . it builds with modern concrete.

Write for free literature. Distributed only in the U. S. and Canada.

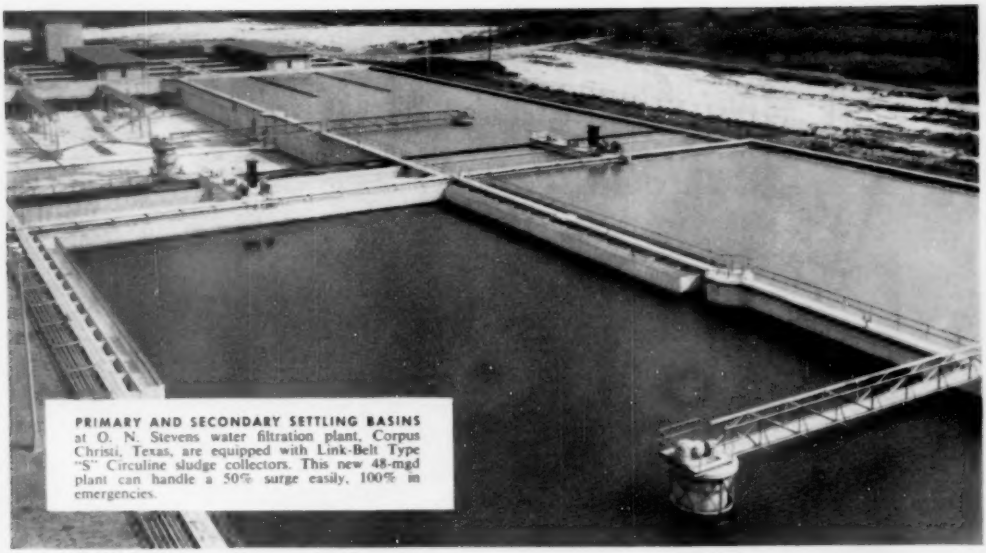
Engineers, Coral Gables project: Smith and Gillespie, Jacksonville, Florida. Contractor: Markowitz Co. Coral Gables, Florida.

PORTLAND CEMENT ASSOCIATION

Dept. 11-76, 33 W. Grand Ave., Chicago 10, Illinois

A national organization to improve and extend the uses of concrete

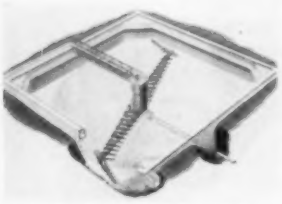
MODERN
concrete



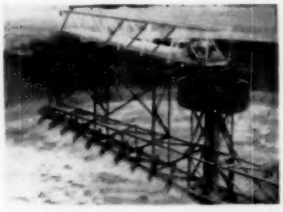
PRIMARY AND SECONDARY SETTLING BASINS at O. N. Stevens water filtration plant, Corpus Christi, Texas, are equipped with Link-Belt Type "S" Circuline sludge collectors. This new 48-mgd plant can handle a 50% surge easily, 100% in emergencies.

Four types of LINK-BELT Circuline collectors

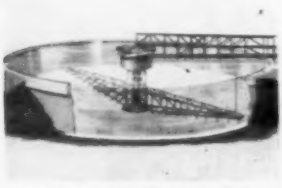
offer positive sludge removal



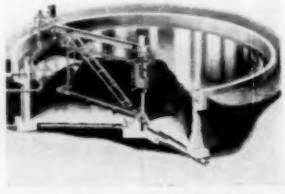
TYPE "S" — specially designed for square and rectangular tanks. As collector revolves, pivoted arms on ends of rakes adjust to thoroughly remove sludge from basin corners.



TYPE "R" — available in models for bottom feed, side feed or cross flow applications . . . in a wide range of sizes. Pitched blades gently convey sludge to center of tank.



TYPE "T" THICKENER — for rugged duty. Similar to "R" collectors except for heavier design. Furnished with fixed rake and automatic or manual lift types.



TYPE "C" — uses simple, positive traction drive to rotate bridge. Slow-speed straightline collector, with long-wearing, corrosion-resistant chains, removes sludge.

There's a design to fit any requirement of tank capacity or construction

THERE's no problem of septicity in settling tanks where Link-Belt Circuline collectors are used. Traveling smoothly and gently, they assure minimum disturbance of flow and the greatest possible concentration and removal of solids in least time.

This efficiency is typical of all the equipment in the complete Link-Belt line for water, sewage and industrial liquids treatment. And it testifies to the value of Link-Belt's more than 35 years' experience in sanitary engineering.

Link-Belt will gladly work with your consultants and chemists on *any* treatment problem. Call your nearby Link-Belt office.

LINK-BELT

SANITARY ENGINEERING EQUIPMENT

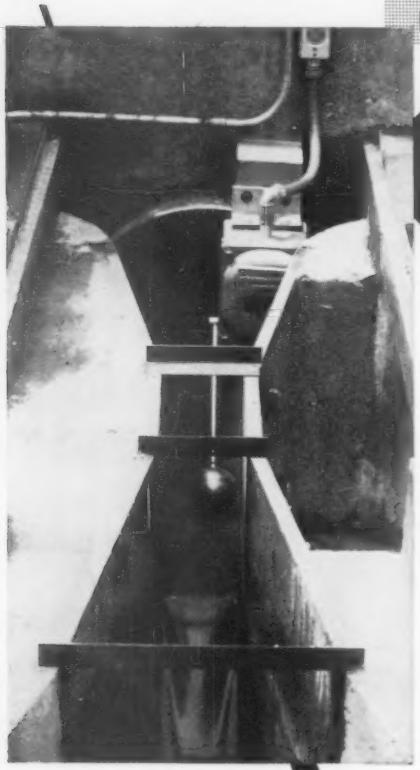
LINK-BELT COMPANY: Executive Offices, Prudential Plaza, Chicago 1. To Serve Industry There Are Link-Belt Plants and Sales Offices in All Principal Cities. Export Office, New York 7; Canada, Scarboro (Toronto 13); Australia, Marrickville (Sydney), N.S.W.; South Africa, Springs. Representatives Throughout the World.

14,854

...A New Concept in Measuring Flow

Through Parshall Flumes

NOTHING ELSE LIKE IT!

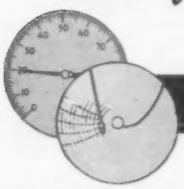


The BURGESS-MANNING Type "ML" METER

Completely eliminates

- Excavation of dry well foundation.
- Concrete dry well foundation and walls.
- Metal float well and cover.
- Connecting telltale piping, valves and fittings between Parshall Flume and float well.
- Float cable and protecting piping.
- Clear water piping and fittings for back-purge system.
- Metal grating to cover dry well.

Think of the savings!
Think of the elimination of maintaince!



Write for Burgess-Manning "ML" Meter Bulletin

BURGESS-MANNING COMPANY

Penn Instruments Division

4122 Haverford Ave., Philadelphia 4, Pennsylvania

Instrumentation and Controls for water, steam, gases, sewage and industrial wastes

ODOR COMPLAINTS?

End them with OZENE®!

End obnoxious odors—and the troublesome complaints they cause—quickly, easily, economically by using OZENE, the tested and proved material that controls odors two ways. OZENE's dual action (1) masks existing odors while it (2) attacks the causes of odors—sulphide-forming bacteria and mold microorganisms.

OZENE is currently being successfully used in:

sewage, leather and rendering plants
land-fill waste disposal projects
dried milk, cheese, cannery and other food plants
industrial lagoons
new excess-capacity sewers
drainage ditches
incinerators
storm sewers
sewer breaks
sludge de-watering
fish-market areas
refuse cans and trucks
kennels, etc.

OZENE is a concentrated material and only small amounts are required for most applications. For odor-controlling sprays, OZENE can be diluted as much as 100-to-1.

Write Solvay® specifying items desired (no cost):

1. OZENE test samples.
2. Data—If you will describe your particular problem, we will be glad to send data.

Allied Chemical

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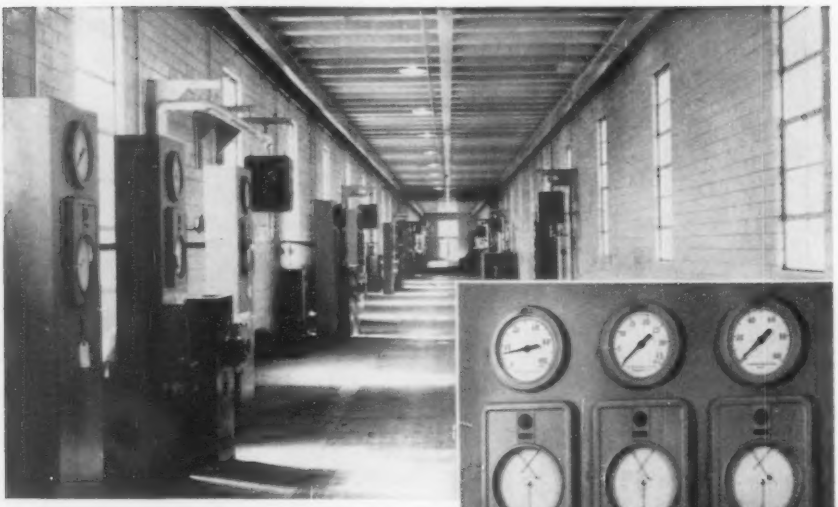

Figure 1—Aeration gallery, showing Bailey Meters which measure the aerated sewage, air, and return sludge.

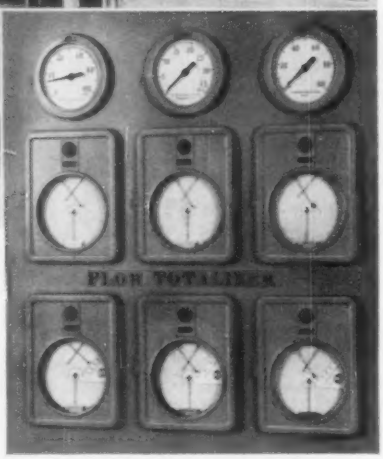

Figure 2—Bailey Electronic Flow Totalizers sum up total sewage, air, and sludge flows measured at individual gallery stations, showing at a glance the plant's performance.

Havens & Emerson—Consulting Engineers

FLOW TOTALIZATION – at Southerly Sewage Treatment Plant

Instantaneous plant performance and operating trends are continuously available to supervisors and operators through Bailey's Electronic Flow Totalizer.

The new 32 MGD addition to the Southerly Sewage Treatment Plant, Cleveland, Ohio is equipped with Bailey Flow Meters, Integrators, Indicators, and Recorders.

Complete instrumentation and automatic controls for sewage and industrial waste treatment plants are engineered and manufactured by Bailey to meet the most rigid requirements of any size plant.

If you are planning new construction, a Bailey Application Engineer will be pleased to help you lay out your instrument and control requirements. MU-26

WATER & WASTE TREATMENT DIVISION

BAILEY METER COMPANY

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In Canada—Bailey Meter Company Limited, Montreal

BAILEY METERS

Specify IOWA for every job

Iowa's complete line of valves for treatment plants assures you of efficient operation, low maintenance cost, and replacement parts when needed in years to come.

IOWA CHECK VALVES—Swing gate type for use in either horizontal or vertical pipe lines. Bronze trimmed throughout. Stainless steel hinge pins. Leather or rubber faced gates, or solid bronze, as desired—aluminum gates available for air service.

IOWA MEDIUM AND LOW PRESSURE VALVES—either non-rising stem or outside screw and yoke types. Designed as carefully as those conforming to A.W.W.A. specifications but with lighter construction for lower pressures.

Write TODAY for descriptive literature

IOWA FLAP VALVES—all iron; can be furnished with bronze hinge bolts or fully bronze mounted—including bronze bolts, flap ring and seat ring—when required.

CLOW HYDROSTATIC RELIEF VALVES — commonly used in bottom of concrete tanks to prevent ground water from floating the tank. Close-grained cast iron body and lid; lead seat ring and lid ring. Cast iron grate in bottom prevents foreign matter from entering tank.

IOWA PLUG DRAIN VALVES—either rising or non-rising stem type. High strength cast iron bodies; bronze stem, operating nut, disc ring and seat ring; rustproof steel bolts and nuts. Handwheels, extension stems, plain or indicating floor stands if required.

IOWA SLUICE GATES—can be used in lines having both seating and unseating pressures. High strength cast iron, bronze mounted, with solid bronze adjustable wedges. Can be equipped with cylinder or motor unit for automatic operation.

IOWA SHEAR GATES—either all iron or iron, bronze mounted. Gate-seating wedges bolted on, permitting replacement without replacing frame.

For 45 years a reliable source for precision engineered products

IOWA VALVE COMPANY

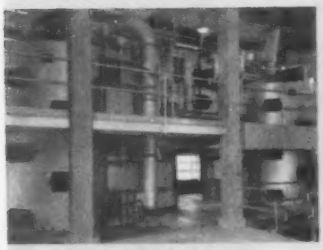
A Subsidiary of James B. Clow & Sons

Oskaloosa, Iowa

the right

Combination...

Design, rugged construction and operating experience are combined in just the right proportions to make Nichols Herreshoff Multiple Hearth Furnaces the most efficient and cleanest of all sewage sludge heat disposal methods.



Burn sewage sludge, grit, skimmings, screenings, or dry sewage sludge in one simple, compact furnace. No offensive smoke, odor, fly ash.

Nichols Herreshoff

Multiple Hearth Dryer - Incinerators

Nichols Engineering & Research Corp.
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A NEW CONCRETE PRESSURE PIPE

of unequalled **ECONOMY**

Recently, a large chemical company in Louisiana selected Cen-Vi-Ro Concrete Pressure Pipe to move fresh water into its new plant. Cen-Vi-Ro easily exceeded the hydrostatic and other test requirements, insuring the owners a permanent and maintenance-free installation. The close tolerances of Cen-Vi-Ro's precision-formed joints . . . measured in thousandths . . . combined with special O-ring type Rubber Gasket Seal assure perfect leakproof connections under even the most adverse field conditions.

Lower first cost plus longer lengths result in a more economical installation . . . *every time!*

Write for complete Cen-Vi-Ro information . . .

THE NAME, ITSELF, MEANS THE WORLD'S FINEST PIPE!

CEN — VI — RO

CEN comes from CENtrifugally spinning the very dry "earth-moist" mixture, fed into the form by belt conveyor in uniform layers.

VI comes from VIbration of the spinning form during the charging period. Specially designed vibrator-tampers on the underside of the form do this job.

RO comes from ROlling the mixture under great pressure applied by a specially designed steel roller.

"Organized for Service"

Vulcan Materials Company

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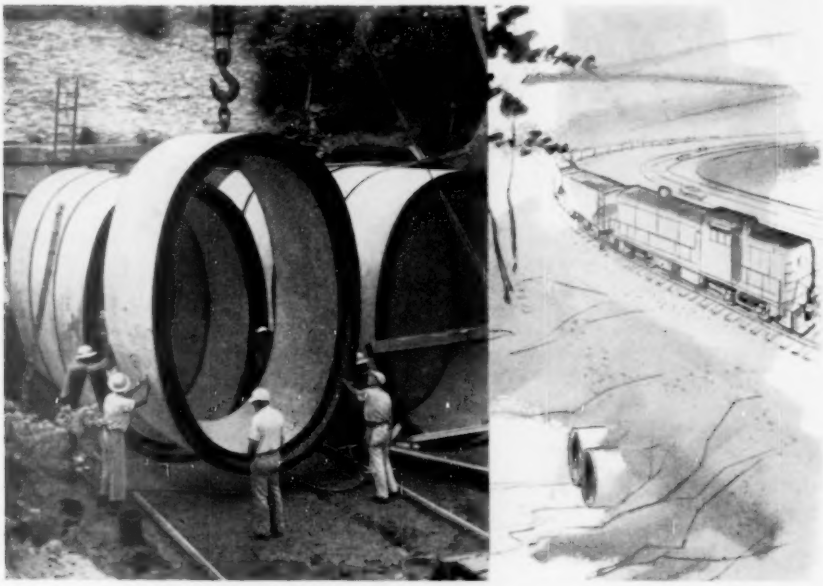

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SEWAGE AND INDUSTRIAL WASTES

Journal of the Federation of Sewage and Industrial Wastes Associations

Volume 30 **November 1958** **Number 11**

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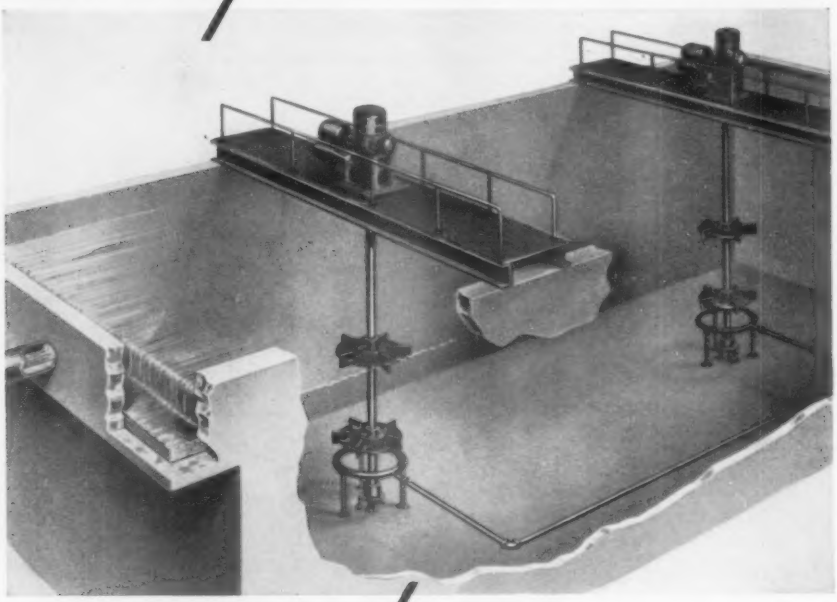

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Sewage Works

DESIGN PRACTICES AND COSTS FOR SMALL SECONDARY SEWAGE TREATMENT PLANTS IN THE UPPER MIDWEST

By D. H. Howells and D. P. Dubois

Respectively, Chief of Evaluation Unit and Staff Sanitary Engineer, Construction Grants Section, Water Supply & Water Pollution Control Program, USPHS, Washington, D. C.

The passage of Public Law 660, 84th Congress, marked the first time that Congressional policy included grants for the construction of sewage treatment works as an integral part of federal financial assistance for the prevention and control of water pollution. House Report 2190, 84th Congress, states that the purpose of this aid is "to accelerate local programs of treatment works construction by providing an incentive to take action now to clean up the waters of the country."

The initial phase of the Public Health Service's administration of the Construction Grants Program was concerned with essential administrative mechanisms. As the program progresses, however, increasing emphasis is being placed upon the collection and evaluation of engineering, financing, and pollution data.

Three aspects of sanitary engineering planning, design, and construction are being investigated at the present time. These include (a) a review of sanitary engineering design practice, (b) planning for the operation and maintenance of completed plants, and (c) the accumulation of current construction costs for projects being built under the Construction Grants Program. In the interest of simplicity and economy, studies of engineering design practice are being restricted to a limited number of projects in various major regions of the country. Operation and maintenance planning and current construction costs will be studied in detail on a comprehensive national basis in a future phase of the program.

This report includes a study of sanitary engineering design practice and construction costs and a preliminary review of provisions made for the financing of operation and maintenance for 20 small secondary sewage treatment plants being constructed in the States of Wisconsin, Illinois, Indiana, Michigan, and Ohio. Four plants from each of these five States were selected at random for this study. The median design population of the 20 projects conforms closely with that of all projects receiving federal financial assistance under P. L. 660. Project design populations range from 600 to 12,500.

All projects studied are located in States concerned with the development of the "Ten State Standards" (1) and, therefore, are committed to use these standards as a guide in the review of plans and specifications for sewage treatment plant construction.

Design Practices

Basis for Design

Estimates of future populations were most commonly made by extrapolating municipal population growth

curves. In instances where unusual conditions were anticipated, such as proximity to a large metropolitan area, special estimating methods were used. For this the usual practice involved a comparison with communities which had experienced similar conditions.

Sewage flows and strengths were ordinarily estimated by the adoption of the arbitrary values of 100 gpd/cap average flow and 0.167 lb of 5-day BOD per capita per day. In some cases, flow measurements of short duration were made, but the results were apparently used only to confirm the assumed flow. In two instances, a percentage of the annual water consumption was employed as the design flow.

The "Ten State Standards" recommend that sewage treatment plants should be designed for 100 gpd/cap domestic sewage flow where there is no existing sewage collection system from which the flow can be gaged. Most of the plants involved in this study were designed for this arbitrary flow regardless of whether or not the flow could be measured. Industrial waste loads were usually assumed rather than measured. Frequently, the estimates were based on standard figures for raw product handled or units of product manufactured. When the industrial waste load was found to represent an appreciable portion of the total load, more elaborate studies were made. Table I summarizes the basic design data for these projects.

TABLE I.—Basic Design Data

Item	Range	Median
Design population	600–12,500	3,350
Design population equivalent (BOD)	1,050–12,500	3,650
Design flow (mgd)	0.105–1.250	0.335
Ratio of maximum to average design flows:		
Combined sewer system	1.50–3.0	2.5
Sanitary sewer system	1.35–3.0	1.9
Design period (years)	13–35	23

Screens and Shredders

Hand-cleaned bar screens will be provided for all plants. In 15 cases they will be utilized as auxiliary units to comminuting devices. Design data are shown in Table II.

TABLE II.—Screening and Grinding Equipment

Type of Unit	Number	Range	Median
Bar screen opening (in.):			
Combined sewers	11	½–2	1½
Sanitary sewers	9	½–1¼	1
Cutters and shredders:			
Comminutors	10	—	—
Barminutors	5	—	—

Bypass Devices

Half of the plants involved in this study will include facilities for the complete bypass of the treatment plant structure. Diversion devices include manually operated shear gates, stop plates, or automatic overflow pipes with the invert elevation above that of the plant influent line. The remaining plants will all include bypass facilities around some or all of the individual units. Stop plates designed to serve as submerged weirs during excess flow, or which could be lifted to bypass all flow, were most frequently specified as control devices.

Grit Chambers

Grit chambers will be provided for all plants serving combined sewer systems and for one plant of the 9 serving sanitary sewer systems. In the latter instance, the need for the grit chamber in the treatment of sewage from a separate sewer system was not explained in the engineering report.

A majority of the grit chambers were designed as long narrow channels with rectangular cross sections and have bottoms sloping to a grit collection channel. Both proportional weirs and Parshall flumes will be used as velocity control devices, with proportional weirs predominating. Trapezoidal channel cross sections and multiple rectangular channels are also to be used in some cases for velocity and surface overflow rate control. A majority of the grit chambers will be

TABLE III.—Grit Chambers

Type of Unit	Range	Median
Conventional grit chamber:*		
Surface overflow rate (gpd/sq ft)	3,330–20,800	8,820
Velocity (fps)	0.5–1.0	0.7
Aerated grit chambers:†		
Surface overflow rate (gpd/sq ft)	2,600–11,900	5,800
Detention time (min)	7–12.5	10

* Total of 8.
† Total of 4.

provided with mechanical grit collection equipment.

Surface overflow rates and velocities for the average design flows are shown in Table III. The average flow design velocities fall within the 0.5 to 1.0 fps limitation recommended by the "Ten State Standards," and the overflow rates are considerably less than the generally recognized maximum for 0.2 mm sand particles.

Primary Sedimentation

A wide variety of devices will be utilized for the purpose of obtaining an even distribution of flow throughout the cross section of the tank. The inlet device in most common use involves a lateral channel with horizontal or vertical ports to the tank. Approximately half of the designs called for baffles immediately downstream from the influent ports. Three of the plants include a more unique design in an effort to gain the desired reduction in velocity head and even flow distribution. In one instance, a "T" fitting will be attached to the influent pipe with 90-degree elbows connected to the ends of the "T," causing the flow to divide and discharge upward beneath the water surface. Another plant will utilize only the "T" fitting to divide the flow and discharge it laterally across the tank. The third device consists of a 180-degree elbow connected to an extension of the submerged influent line and will discharge the incoming flow against the influent end of the tank.

Surface and weir overflow rates and detention times are summarized in Table IV. With few exceptions, design surface overflow rates for both circular and rectangular tanks were less than the maximum of 1,000 gpd/ sq ft specified by the "Ten State Standards." However, weir overflow rates for rectangular tanks will exceed the recommended rate of 10,000 gpd/lin ft of weir in four plants.

Smooth overflow weirs outnumbered serrated weirs by 11 to 6. In most cases the serrated weir was of the "V-notch" type, but in one instance the notch had one vertical edge and one sloping edge. Another design called for rectangular notch weirs. The median design flow of plants using serrated weirs did not vary materially from that of the plants which employed smooth weirs.

TABLE IV.—Primary Sedimentation

Type of Unit	Range	Median
Rectangular tanks:*		
Surface overflow rate (gpd/sq ft)	400–890	700
Weir overflow rate (gpd/lin ft)	5,550–30,000	9,640
Detention time (hr)	1.6–3.8	2.0
Circular tanks:†		
Surface overflow rate (gpd/sq ft)	650–1,080	715
Weir overflow rate (gpd/lin ft)	4,030–10,750	4,500
Detention time (hr)	1.6–2.1	1.8
Spiragesters:‡		
Surface overflow rate (gpd/sq ft)	390–630	—
Weir overflow rate (gpd/lin ft)	2,250–3,990	—
Detention time (hr)	1.7–2.5	—
Imhoff tanks:§		
Surface overflow rate (gpd/sq ft)	590	—
Detention time (hr)	2.8	—

* Total of 12.
† Total of 5.
‡ Total of 2.
§ Total of 1.

All primary sedimentation tanks will be provided with mechanical scum and sludge collection devices of standard design.

Activated Sludge

The median design flow of the six activated sludge plants examined in this study did not vary substantially from that of the trickling filter plants. There seemed to be no tendency to restrict the use of this form of biological

TABLE V.—Activated Sludge

Type of Unit	Range	Median
Diffused air:*		
Loading (lb BOD/1,000 cu ft)	21.2–28.1	24.1
Detention time (hr)	6.1–10.1	6.9
Air supply (cu ft/lb BOD)	870–1,530	1,090
Sludge return (% design flow)	25–36	25
Mechanical aeration:†		
Loading (lb BOD/1,000 cu ft)	34.5	—
Detention time (hr)	13.0	—
Air supply (cu ft/lb BOD)‡	530	—
Sludge return (% design flow)	17	—

* Total of 5.
† Total of 1.
‡ Based upon manufacturer's specification for "Cavitator" aerator.

treatment to plants of greater than 1.5 mgd capacity as recommended in the "Ten State Standards."

Five activated sludge plants will be of the conventional type involving diffused aeration with sludge return to the aeration tank influent at a rate approximating 25 per cent of design flow. The remaining plant was designed for mechanical aeration with a sludge return equal to about 17 per cent of design flow. Two plants will be provided with pre-aeration for raw sewage prior to primary sedimentation. Four of the six plants will provide two parallel aeration tanks as suggested in the 'Ten State Standards." Table V summarizes the major design data for the activated sludge units. These data conform reasonably well with recommended standards and practice.

Trickling Filters

Fourteen of the 20 plants included in this study will utilize trickling filters as secondary treatment units. These include eight standard-rate and six high-rate filters of varying design. Pertinent design data are shown in Table VI.

Two of the eight standard-rate filter installations provide for two filters in parallel with equal distribution of flow to each. Provisions for recirculation were also made in two of the plants.

Three of the high-rate plants will use recirculation patterns of the Accelo type with unsettled filter effluent recirculation to the filter influent. One of these plants will provide two-stage filtration, with a recirculation rate of 0.5:1 around the primary filter and 1:1 around the secondary filter. The other two Accelo plants will be single-stage installations with recirculation rates of 0.9:1 and 1.2:1, respectively.

Biofiltration recirculation plans were used for two plants. One of these will be a two-stage plant with primary filter effluent return to the primary clarifier and secondary clarifier effluent return to the secondary filter, both at 1:1 recirculation rates. In the other plant of this type, flow emanating from the bottom of the secondary clarifier will be returned to the primary clarifier at a recirculation ratio of 0.2:1.

The third type of high-rate trickling filter found in this study was a single-stage Aero filter. In this design, secondary clarifier effluent will be returned to the filter during periods of low flow to maintain a minimum dosing rate of 13 mgd/acre. This rate will be provided without recirculation at normal design flow.

Filter material specified included slag, trap rock, granite, limestone, and unspecified types of rock, gravel, or stone. In all cases, however, the material will be required to meet standard quality specifications. Specified filter media size generally ranged from two to four inches.

With two exceptions, the filter walls will be constructed with poured-in-place, reinforced concrete. Reinforced masonry block walls are to be used in the remaining two plants.

TABLE VI.—Trickling Filters

Type of Unit	Range	Median
Standard rate:*		
Depth (ft)	5.0–6.3	6.0
Dosing rate (mgd/acre)	2.0–3.7	3.2
Loading (lb BOD/1,000 cu ft)	6.7–16.0	13.9
High rate:†		
Depth (ft)	3.0–6.3	5.4
Dosing rate (mgd/acre)	9.9–30.7	17.7
Loading (lb BOD/1,000 cu ft)	34.8–107	49.7

* Total of 8.
† Total of 6.

In a number of instances there were no specifications for the channel size and surface opening of filter underdrain blocks. When specified, channel openings varied from 25 to 30 sq in. per block with surface openings approximating 25 per cent of the total surface area.

Nine of the 14 trickling filter plants will be provided with peripheral vents at the filter wall. In five of the plants additional ventilation is to be provided through use of vent pipes extending from the peripheral vent up through the filter media. Two designs utilized vent pipes extending upward from the central drainage channel. The three remaining plants will rely upon ventilation through the drainage channel and underdrain system. None of the designs called for forced air ventilation.

Secondary Sedimentation

Most secondary sedimentation tanks were similar in design to the primary tanks. Notable exceptions were two small tanks which will not be equipped with mechanical sludge removal devices and one Spiraflo clarifier. The two nonmechanical tanks will follow trickling filters. The sludge well in one of the rectangular tanks is to be located at the effluent end.

Sludge from six tanks will be discharged to digesters, and in one plant to a vacuum filter. In the remaining 14 examples, the sludge is to be returned to either the primary clarifier or the activated sludge aeration tanks.

TABLE VII.—Secondary Sedimentation

Type of Unit	Range	Median
Rectangular tanks:*		
Surface overflow rate (gpd/sq ft)	380–1,010	650
Weir overflow rate (gpd/lin ft)	4,170–14,300	6,670
Detention time (hr)	1.3–3.8	1.9
Circular tanks:†		
Surface overflow rate (gpd/sq ft)	690–855	770
Weir overflow rate (gpd/lin ft)	2,700–8,610	4,500
Detention time (hr)	1.4–2.1	1.9

* Total of 13.
† Total of 7.

As can be seen from Table VII, surface and weir overflow rates conform very closely to the 800 to 1,000 gpd/sq ft and 10,000 gpd/lin ft, respectively, recommended by the "Ten State Standards." The single exception involved a tank following a standard-rate trickling filter where the weir overflow rate will exceed the recommended value by 50 per cent, at the average design flow.

Sludge Digestion and Drying

Separate sludge digestion will be provided for 16 of the 20 plants. One plant will use vacuum filtration of raw sludge, two plants, Spiragesters, and one plant, an Imhoff tank.

Thirteen plants were designed for heated digesters using external heaters. Twelve of these call for external heat exchangers and one will inject live steam into the raw sludge and sludge recirculation lines. Ten plants will utilize sewage gas, in conjunction with oil or natural gas, to fire the boilers.

Sludge mixing will be provided by sludge recirculation in 15 of the 16 digesters. Provisions were made for adding external heat exchangers in the two unheated digesters where recirculation is to be provided.

With two exceptions, digester supernatant will be discharged to the primary tank influent. In the remaining plants the supernatant is to be discharged to an aeration tank and a trickling filter.

Recommended digester loadings will be exceeded in two instances on the basis of digester volume and design population. However, provisions were made for adding sludge heaters in both plants when population growth requires the added capacity. Table VIII contains design loadings for digesters and drying beds.

Fifteen plants will dewater sludge on open drying beds, two will utilize lagoons, and three will employ mechanical dewatering devices. Sludge

TABLE VIII.—Sludge Digestion and Drying

Type of Unit	Range	Median
Heated digesters:*		
Loading (cu ft/cap)	3.5–6.2	5.1
Unheated digesters:†		
Loading (cu ft/cap)	5.2–7.9	5.3
Sludge drying beds:‡		
Loading (sq ft/cap)	1.0–3.0	1.6

* Total of 13.
† Total of 3.
‡ Total of 15.

bed underdrainage from 12 of the plants is to be discharged to primary clarifiers. In the other three plants the underdrainage will be discharged to the plant effluent. The design sludge drying bed area dropped below the 1.25 to 1.75 sq ft per capita recommended by "Ten State Standards" in a few plants to a minimum of two-thirds of the suggested area.

Three plants will employ sludge lagoons, one in conjunction with a vacuum filter, for sludge dewatering. Facilities will be provided for ferric chloride and lime preconditioning for the sludge going to the two vacuum filters. The third mechanical dewatering device operates on the compression principle and does not provide for sludge conditioning.

Chlorination

Chlorination facilities will be provided in 11 of the 20 plants. Provisions were made for the addition of chlorine to the sewage at one or more of the following points: raw sewage, primary effluent, filter or aeration tank effluent, and final effluent. Five contact tanks are to be used, with the mean detention time being 28 min. The maximum chlorine feed capacity specified for the 11 plants ranged from 15 to 63 ppm, with a median of 27 ppm.

Flow Measurement

Flow measurement devices will be provided in 18 of the 20 plants. These include V-notch weirs, Parshall flumes, Venturi meters, nozzles, and a pump time clock. Recording equipment was also specified in many instances.

Construction Costs

The Construction Grants Program offers a convenient source of construction cost data for sewage treatment works. The Public Health Service has been collecting these data as they become available for machine-card tabulation, analysis, and reporting on a national basis.

The cost data for the 20 projects included in this study display reasonably good correlation with plant design flows and population design figures. These data are shown graphically in Figures 1, 2, and 3. Unit costs are based on prime contract prices for the sewage treatment plant only, and do not include other costs, such as land, engineering, administrative, and legal services. The total first cost of all projects (excluding land) was found to be approximately 20 per cent greater than the contract cost used in developing these cost curves.

Operation and Maintenance

The Federal Water Pollution Control Act states that no grant shall be made for any sewage treatment works project until the applicant community has made provision satisfactory to the Surgeon General for assuring proper and efficient operation and maintenance of the treatment works after completion of construction. Reviews have recently been made of planning by communities for operation and maintenance from data developed by the designing engineers. However, experience to date indicates that there has not been the expected correlation between funds scheduled for this purpose and the size and type of sewage treatment works. Because of this, a study is being instituted for the purpose of determining an improved basis for the evaluation of cost estimates for plant operation and maintenance. If adequate financing is assured, the plant may be operated and maintained in a manner necessary to achieve the degree of treatment an-

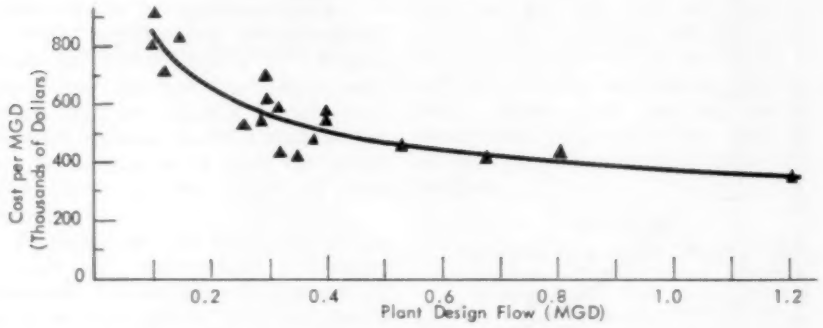

FIGURE 1.—Contract cost per million gallons per day plant capacity.

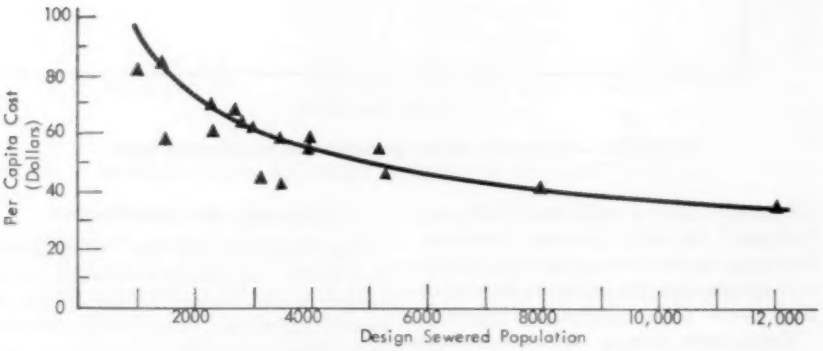

FIGURE 2.—Contract cost per capita.

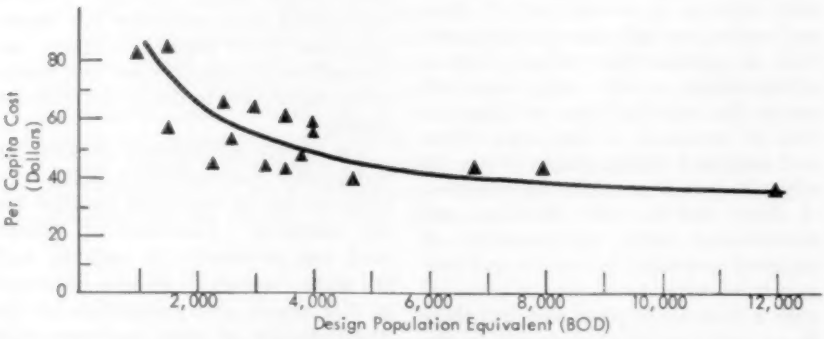

FIGURE 3.—Contract cost per population equivalent.

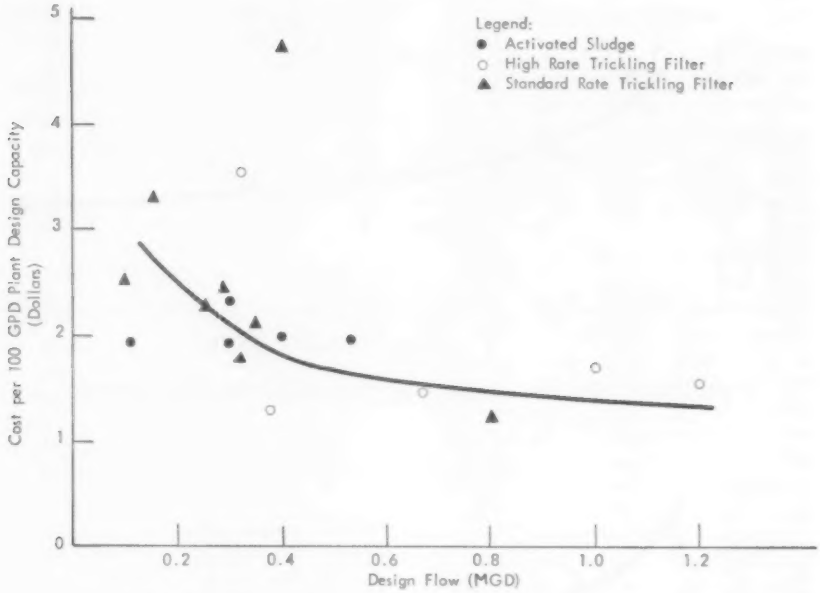

FIGURE 4.—Estimated annual operation and maintenance costs.

ticipated. Unless sufficient funds are budgeted for this purpose, however, little can be done to assure that plants will accomplish the purpose for which they were financed and constructed.

Estimated annual operation and maintenance costs for the plants included in this study are presented graphically in Figure 4. The data do not display the expected relationship between type and size of plant and operation and maintenance cost. This is particularly evident from a consideration of the high cost estimates for standard-rate trickling filters as compared to high-rate filters and activated sludge plants, when the opposite would normally be expected. A sharp rise in unit operation and maintenance costs, representative of minimal operating personnel and certain fixed costs, would also be expected with a decrease in plant size, but there is no evidence of this except in the case of the standard-rate trickling filter plants.

Summary and Conclusions

The influence of the "Ten State Standards" on sewage treatment plant design in the North Central States is readily apparent. With relatively few exceptions, treatment units were designed for recommended loadings.

There was very little evidence of preliminary investigation to determine basic design data. Primary reliance was placed upon arbitrary per capita flows and BOD loads in common use throughout the country and not necessarily applicable to the projects under design.

The design of influent devices for rectangular sedimentation tanks continues to be an empirical exercise for the engineer. Conventional design need not necessarily be rational, and the three "unusual" designs discussed in this report give recognition to the dissatisfaction of some engineers with the usual influent port designs. There appears to be a need for more design-

oriented research directed towards solution of this hydraulics problem.

Wide variations in the provisions made for the ventilation of trickling filters and the fact that many engineers did not specify surface and channel openings in filter underdrains are indications of a need for better guide lines for the design of filter structures.

Planning for the financing of operation and maintenance of sewage treatment plants does not appear to be adequate and greater attention should be given to this problem by the practicing engineer.

The construction cost data for the projects included in this study illustrate the fact that good cost data offering close correlation with types and sizes of projects can be developed if sufficient detailed information is available. These data conform rather closely with preliminary raw data for all new plant construction under this program.

Reference

1. "Standards for Sewage Works, Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, New York, Ohio, Pennsylvania, and Wisconsin." Upper Mississippi River Board of Public Health Engineers and Great Lakes Board of Public Health Engineers, May 1952 (partially revised July 1954).

OPERATION AND MAINTENANCE COST STUDY

The Public Health Service is currently undertaking a study of municipal sewage treatment plant operation and maintenance costs. The study is expected to contribute useful information for sewage treatment planning at all levels of government, and to do this it requires the cooperation of treatment plant personnel and state agencies.

Cost data will be requested during the next few months from approximately 500 well-operated and maintained sewage treatment plants throughout the United States. These communities will be selected by the state water pollution control agencies on the basis of type of treatment provided, years in operation, quality of operation and maintenance, and availability of operating records.

Survey questionnaires will request information relating to the type of plant, plant loading and performance, operation and maintenance costs, personnel requirements, and laboratory control. The quantity of information requested is believed to be minimal for a survey of this kind and should be readily available from existing records.

This survey will provide an opportunity for the sewage treatment plant operator to make a substantial contribution to the art of sewage treatment and the control of water pollution.

BOD PROGRESSION IN SOLUBLE SUBSTRATES *

By A. W. Busch

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There has appeared in the literature in recent years much information casting doubt on the validity of the first order approximation used in comparing the "strength" of organic wastes and in predicting the rate of biological stabilization of putrescible matter in polluted waters. Most of these papers were concerned with industrial wastes, particularly those containing predominantly dissolved organics.

Many workers have pointed out the unreliability of k values as parameters of biological activity and some investigators have proposed theories to justify the apparently erratic characteristics of BOD data. The fact that the progression of biochemical oxidation of domestic sewage sometimes conforms to mathematical formulations other than those expressing the growth of bacteria is an unfortunate coincidence which has frequently caused valid data to be labeled erratic and hence unreliable. Phelps (1), in his analysis of the exponential BOD formulation, recognized the coincidence and discussed at some length the possibility of a compound reaction. However, he concluded that the progression of oxygen utilization in sewage BOD determinations was best formulated by a first order equation. More recently, Hoover *et al.* (2) postulated a two-phase reaction compounded of assimilation and endogenous respiration. This theory ascribes the oxygen utilization during the second phase to the respiration of the bacteria produced during the first phase and thus precludes any growth of predator organisms feeding on the bacterial population.

* Presented at the 13th Industrial Waste Conf., Purdue University; Lafayette, Ind.; May 5–7, 1958.

Theory

The intent of this paper is to show that the process of biological oxidation of soluble organic substrates involves (a) conversion of the material into cell substance with varying degrees of synthesis, and (b) utilization of stored decomposition products (principally glycogen) and of cell substance. The latter phase involves both the oxidative organisms and predatory organisms. The clear delineation of these two steps depends principally upon the microbial population present. A single strain of organisms or a predominance of substrate-consuming organisms over predator organisms yields the most distinct two-stage reaction. As the ratio of predators to substrate-consuming population increases, the separation of the two stages begins to blur. At the population balance typical of stale sewage synergetic activities may produce the first-order oxygen utilization curve so often noted in the analysis of domestic sewages.

A "plateau" of oxygen utilization representing consumption of all substrate occurs generally in from 12 to 48 hr (depending on the lag) and has a characteristic value for a given substrate. Theoretically, at least, this plateau affords a much more valid point for determining total load or "ultimate" oxygen demand than does the conventional 5-day incubation.

Recent Work

In 1951, Busch and Sawyer (3) noted that the 1-day BOD values were by far the most reliable parameter obtainable in work involving a soluble substrate of highly reproducible character, in this case a synthetic sewage.

TABLE I.—BOD Data for a Synthetic Sewage

Exp. No.	BOD (mg/l)					k	L
	1-day	2-day	3-day	4-day	5-day		
1	95	116	157	190	190	0.161	234
2	94	107	157	186	194	0.109	279
3	99	142	167	182	187	0.310	193
4	90	120	164	178	185	0.218	206
5	92	140	162	162	182	0.313	178
6	97	115	129	146	164	0.304	160
7	96	107	121	152	158	0.187	180
8	92	110	123	128	147	0.539	133
9	100	125	164	188	208	0.184	236
10	98	128	156	192	195	0.179	230
11	96	125	164	182	197	0.209	216
$C_v = \sigma/M$	0.03	0.09	0.11	0.12	0.10	0.44	0.18

Independent observations by Garrett and Sawyer (4) in working with the activated sludge process at the same time supported these results. It was also noted that the progression of oxygen utilization did not follow a first-order formulation. These points were discussed by Busch and Sawyer and a tentative theory for the reaction was presented.

It was postulated that the reproducibility of the first day values was due to the nature of the substrate—in that the food was soluble, readily available and was practically all consumed after 24 hr of incubation. It was further theorized that if practically all of the available food had been converted into cell material after 24 hr, then any further oxygen utilization, in excess of the endogenous rate, was due to the activity of protozoa and other higher organisms feeding on the bacteria. This would explain the erratic BOD values obtained for incubation times greater than 24 hr, oxygen consumption being a function of the predator population.

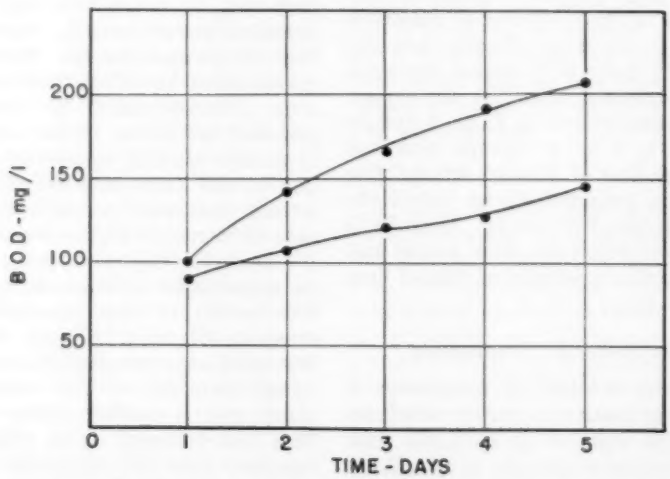

FIGURE 1.—Range of daily BOD values for a synthetic sewage.

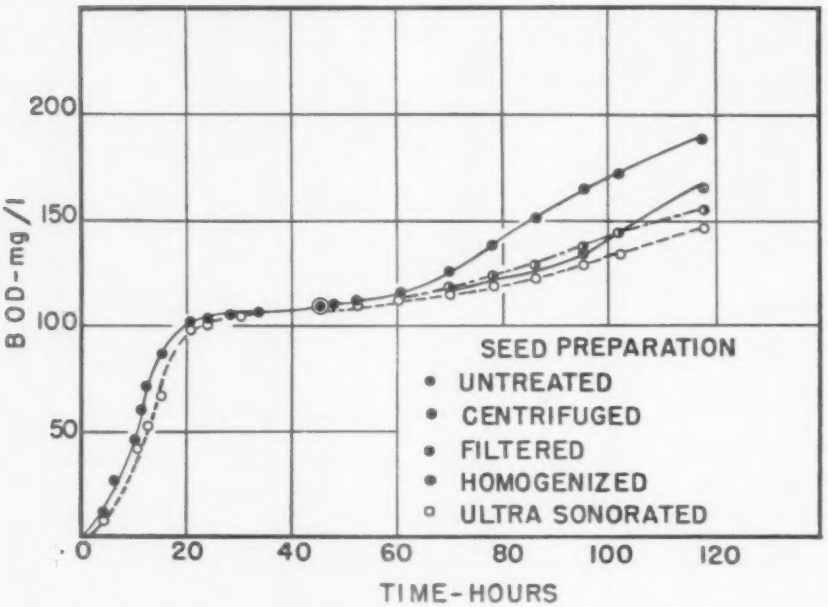

FIGURE 2.—Oxygen utilization of a synthetic sewage by the Warburg apparatus technique.

Results

Table I shows the BOD data and the corresponding k and L values obtained for a synthetic sewage. Of particular import is the progressive daily increase in the coefficient of variation. Figure 1 shows graphically how the range of daily BOD values increased with incubation time. In the experiments summarized in Table I and in Figure 1, 2 ml of sewage seed was used per liter of dilution water. The seed was prepared 48 hr before the BOD samples were set up. Each BOD value was based on three blanks and seven replicate samples of diluted synthetic sewage.

Seed and Substrate Preparation

In order to follow the progression of oxygen utilization in greater detail, experiments were set in duplicate with the Warburg respirometer. Synthetic sewage was used as substrate with domestic sewage seed. The seed was treated by various means designed to reduce the predator population without seriously affecting the viability of the bacteria. Seed preparations used were untreated, homogenized, and ultra-sonorated sewage and the supernatant from centrifuged sewage. Horton (5) demonstrated the effectiveness of short-term ultra-sonoration in destroying protozoa and other higher organisms in sewage without appreciable reduction of the bacterial population. No attempt was made to completely eliminate all forms of higher organisms in the seed, the objective being simply an appreciable decrease in numbers. The results of this experiment are shown in Figure 2. Clearly shown is the multi-stage progression typical of soluble substrates. The assimilation phase was completed within 24 hr. This was followed by a plateau of relatively slow rate of oxygen utilization characteristic of endogenous res-

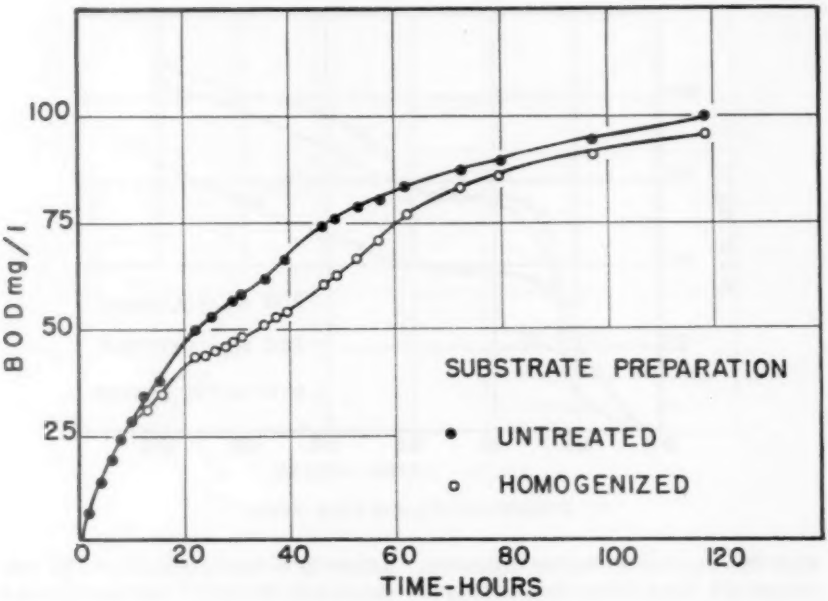

FIGURE 3.—Oxygen utilization of a domestic sewage by the Warburg apparatus technique.

piration. It is noteworthy that all samples were in agreement through 60 hr of incubation. Subsequently there was a pronounced increase in the rate of oxygen utilization. Obviously microbial growth was involved and it is noted that the untreated sample showed a greater extent of growth than the samples that were treated to reduce the predator population.

Figure 3 shows results obtained in a similar experiment with domestic sewage in the Warburg apparatus. These data show that the progression of oxygen utilization in homogenized sewage differs appreciably from that of untreated sewage. This difference is attributed to reduction of the initial predator population in the homogenized sample. It may be speculated from these data that BOD curves for domestic sewage often conform closely to the first order formulation because of the heterogeneous, acclimated microbial population in the sewage.

Subsequent investigations were conducted using the conventional incubation technique to determine the nature of the BOD reaction in dilutions applicable to waters polluted with soluble organic wastes. Figure 4 shows typical curves obtained for glucose, peptone, and a synthetic sewage containing glucose, starch, peptone, and soap. In all instances the typical multi-stage reaction was observed.

Seeding Effects

A series of BOD experiments were conducted using the synthetic sewage and glucose as substrates in the dilution technique with the objective of determining whether increased quantities of sewage seed could produce the plateau in 24 hr since optimum reproducibility of 1-day data should thus be obtained. The experiments were set with two seed quantities, 2 and 10 ml of sewage per liter of dilution water. The seed was not treated to re-

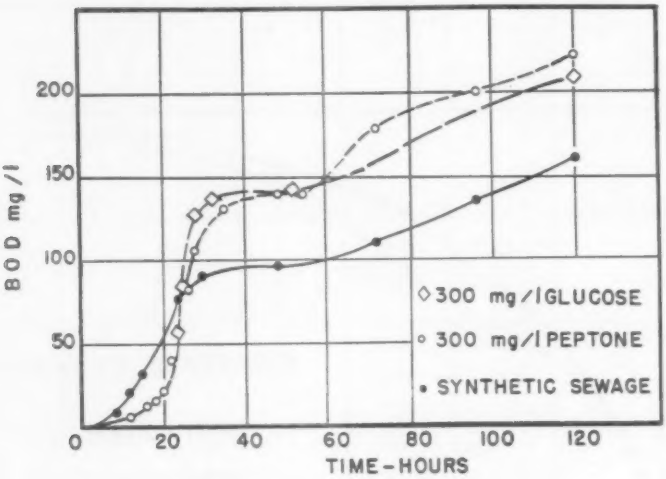

FIGURE 4.—Typical BOD curves.

duce the number of higher organisms present nor was a pre-seeding technique employed. The results of these experiments, tabulated in Table II, indicate that quantity of seed is a factor in the location of the beginning of the plateau. Other experiments showed that 25 ml of sewage seed per liter of dilution water caused undesirable depletion in the blanks and did not reduce the time for reaching the plateau appreciably below that found with 10 ml of seed. As will be shown later the nature and concentration of the substrate may also affect the time required to achieve the plateau.

The studies described above were completed in May 1952. Resumption of the investigation was initiated in the fall of 1957. Several months were devoted to further exploratory experiments on the advantages of pre-seeding over other seed preparation techniques, such as filtering, centrifuging, etc. The conclusion reached was that filtration of sewage which had been settled

TABLE II.—Effect of Quantity of Seed

Run No.	Substrate	BOD (mg/l)					
		1-day		5-day		20-day	
		2* (ml/l)	10* (ml/l)	2* (ml/l)	10* (ml/l)	2* (ml/l)	10* (ml/l)
1	Glucose	7	95	211	241	228	242
2	Glucose	4	99	212	213	218	223
3	Glucose	9	99	207	224	219	234
4	Glucose	2	101	191	211	233	234
5	Syn. sewage	78	100	162	175	187	201
6	Syn. sewage	51	88	196	218	255	286
7	Syn. sewage	51	93	175	195	218	224
8	Syn. sewage	81	93	177	194	208	216
9	Syn. sewage	43	92	175	206	209	209

* Seed added.

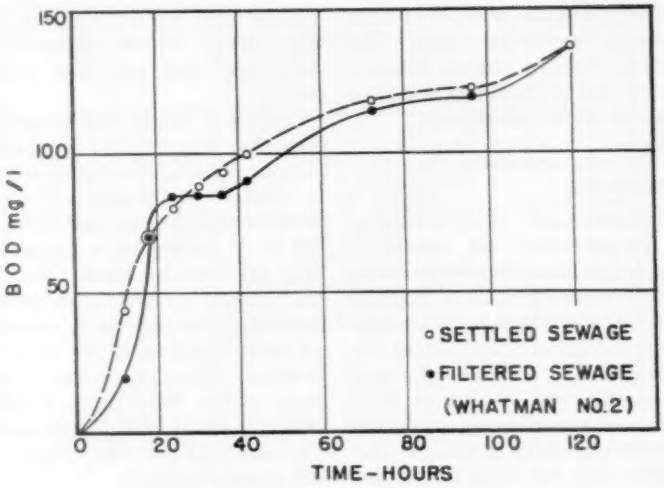

FIGURE 5.—Effect of filtration on BOD.

for 24 hr was the simplest procedure and yielded satisfactory two-stage oxygen utilization curves. A two-stage reaction was always noted in the BOD analysis of soluble substrates whether the seed was treated or untreated, but filtration improved the distinction between the two phases. The effectiveness of filtration through Whatman No. 2 filter paper in changing the progression of oxygen utilization in settled domestic sewage is shown in Figure 5.

The following experiments were conducted by the dilution technique in order to utilize the most widely practiced procedure. Substrates were limited to glucose, glutamic acid, and a mixture of these because the well-defined 5-day BOD values established by Sawyer *et al.* (6) served as a check on

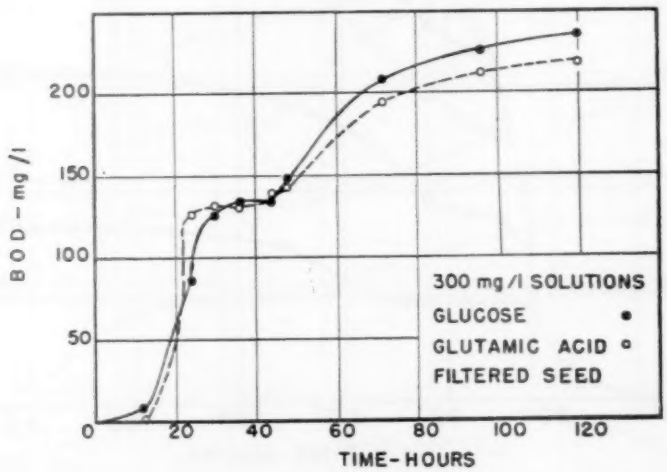

FIGURE 6.—Typical BOD curves.

seed viability and the absence of toxic compounds in the dilution water. Figure 6 shows typical curves obtained for glucose and glutamic acid during this phase of the investigation.

BOD, Substrate, and Time Relationships

These experiments, using a variety of seed preparations and quantities, indicated a reproducible plateau value for a single concentration of a given substrate. If the plateau does represent nearly complete conversion of initial substrate to bacterial cells and stored material, then a plot of BOD at the plateau versus concentration of substrate should yield a straight line relationship with the slope of the line representing that portion of the substrate which is completely oxidized. Accordingly, an experiment was devised wherein replicate samples were set with substrate quantity ranging from 1 through 6 mg per BOD bottle. Each analysis was based on three blanks and three replicate samples. Five ml of filtered 24-hr old sewage seed was used per liter of dilution water.

Figure 7 shows the progression of oxygen utilization for various glucose concentrations. In Figure 8 data from a similar experiment are plotted as BOD versus glucose and show that by 48 hr of incubation a linear relationship has been achieved. The delay in the higher concentration samples in achieving the plateau is characteristic of glucose although the three highest dilutions were linear after 28 hr. The slope of the 48-hr curve is 0.47, indicating a BOD of 0.47 mg per mg of glucose or 44 per cent of the theoretical oxygen demand.

Figures 9 and 10 show similar data for glutamic acid. With this substrate a linear relationship between BOD and glutamic acid was noted for all concentrations within 24 hr of incubation. In most cases the variation in 24-hr data is less than in 5-day results. The slope

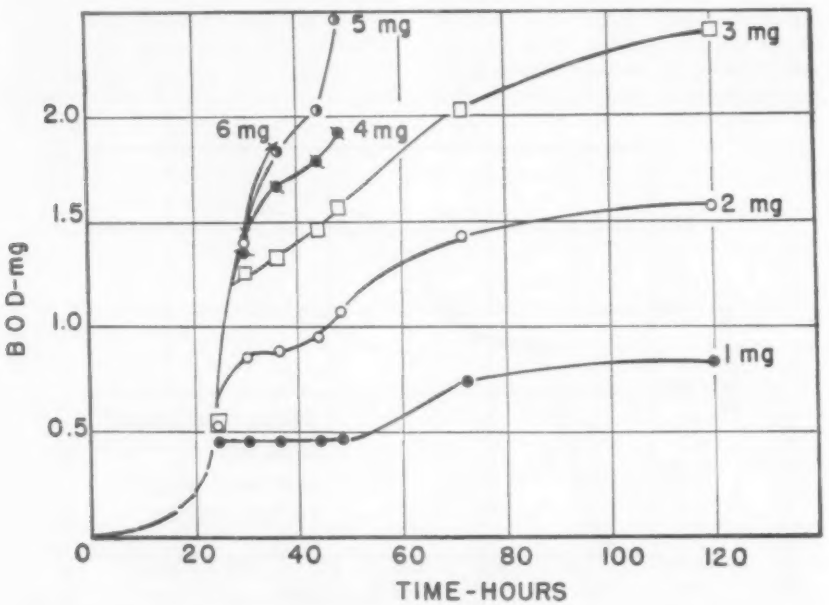

FIGURE 7.—BOD progression for various glucose concentrations.

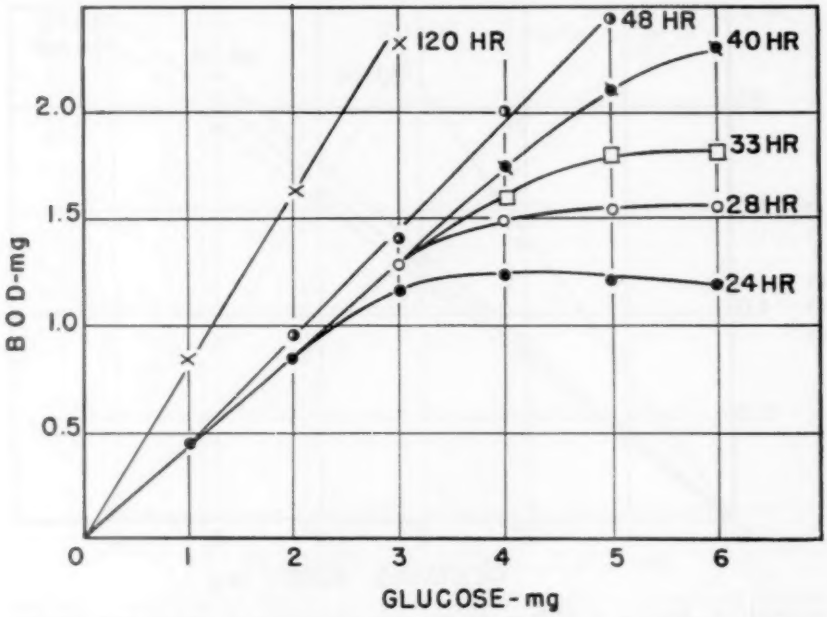

FIGURE 8.—Relation of BOD to glucose concentration at various time intervals.

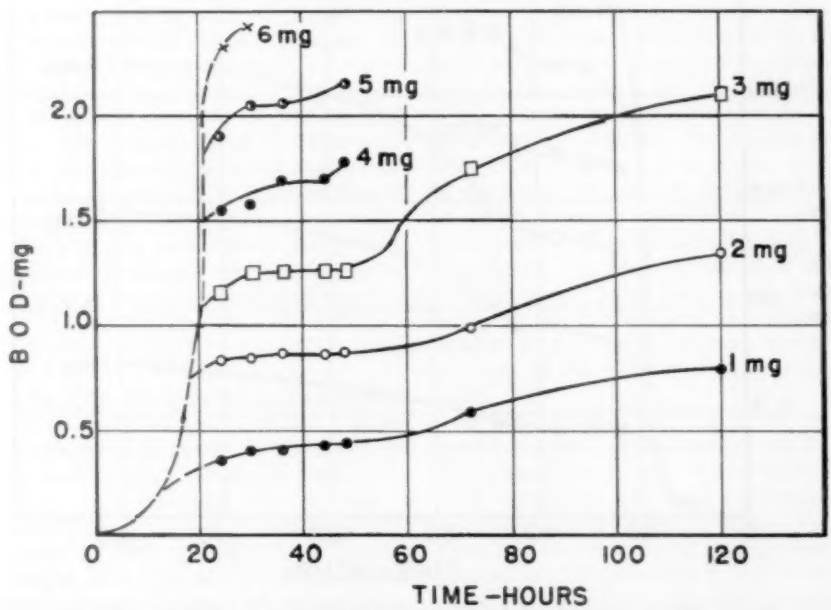

FIGURE 9.—BOD progression for various glutamic acid concentrations.

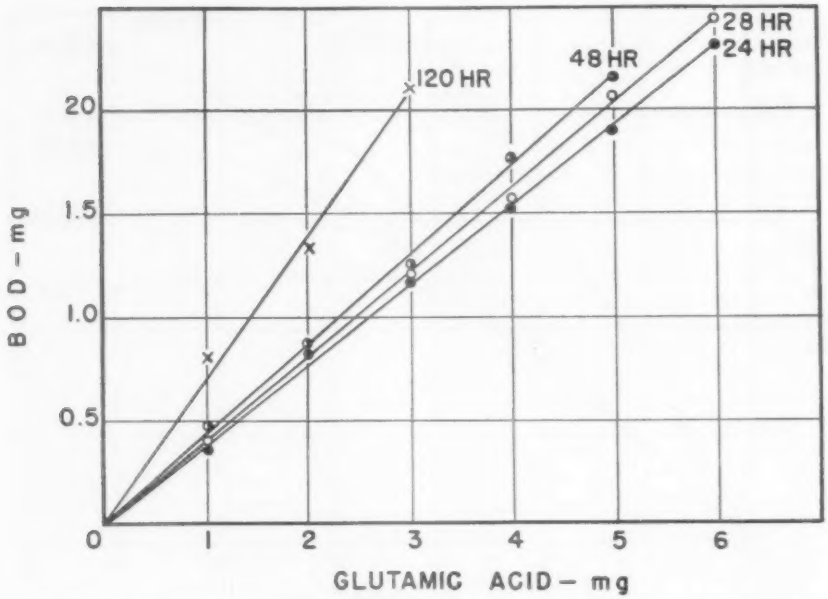

FIGURE 10.—Relation of BOD to glutamic acid concentration at various time intervals.

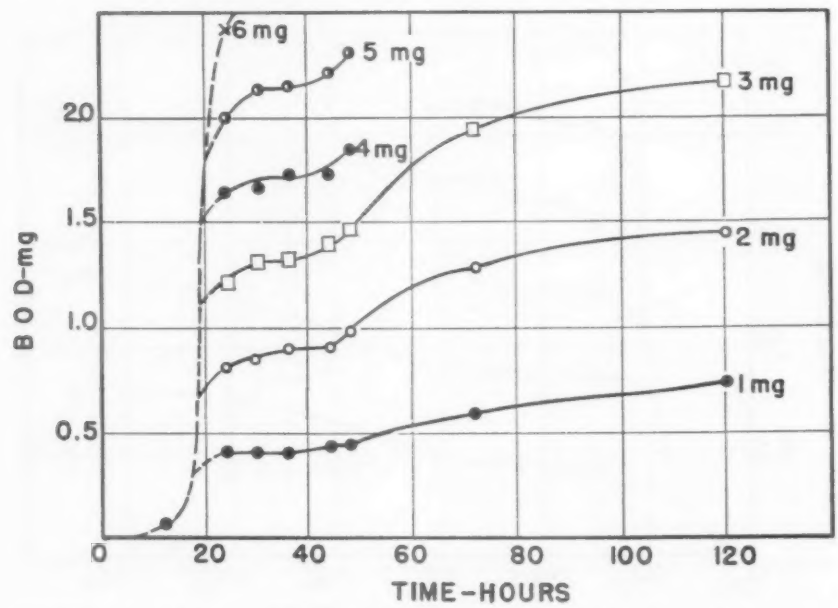

FIGURE 11.—BOD progression for various concentrations of 1:1 mixture of glucose and glutamic acid.

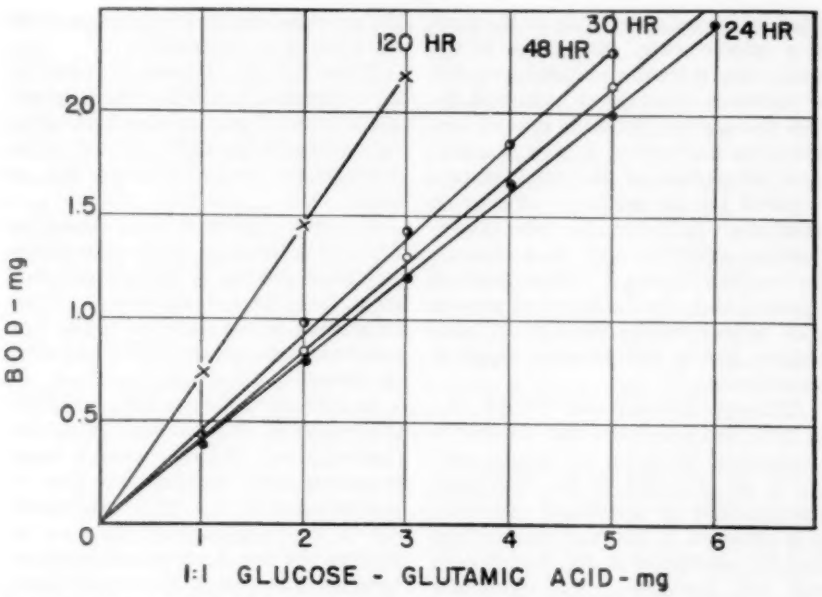

FIGURE 12.—Relation of BOD to concentration of 1:1 mixture of glucose and glutamic acid at various time intervals.

of the 24-hr curve (Figure 10) is 0.385, indicating a BOD of 0.385 mg per mg glutamic acid or 39 per cent of the theoretical oxygen demand.

The results of a typical experiment with a 1:1 mixture of glucose and glutamic acid are shown in Figures 11 and 12. The data do not show the delay in achieving a linear relationship characteristic of glucose alone. The slope of the 24-hr curve indicates a BOD of 0.404 mg per mg of mixed substance or approximately 39 per cent of the theoretical oxygen demand.

Discussion

In 1936, Barker (7) reported studies of the oxidative metabolism of a single strain of algae utilizing a variety of carbonaceous substrates, including glucose. He concluded, "The process of assimilation of these compounds proceeds in two experimentally distinct stages. The first, which has been called the primary process of assimilation, consists of an oxidative conversion of the substrate into a carbohydrate which is stored in the cells as glycogen. The formation of this carbohydrate is rapid compared to its subsequent decomposition in the process of cell synthesis which constitutes the second stage of assimilation. Further, it is formed with great economy; from 50 per cent to more than 80 per cent of the carbon of the substrate is assimilated depending upon the organic compound used." Specifically, Barker reported that the most probable value of oxygen consumed in the first stage of glucose utilization by this single organism was 30 per cent of the theoretical oxygen demand.

In 1939, Clifton and Logan (8) reported similar studies using the familiar organism *E. coli*. These investigators studied a variety of substances, including glucose, and reported, "The oxidation of a number of organic compounds by suspensions of *E. coli* is not carried to completion, but that instead a portion of the compound is assimi-

lated by the cells, probably in the form of a carbohydrate. Regardless of the initial concentration or total quantity of substrate, the oxygen consumed before the marked break in rate of consumption is observed is always a constant proportion of the total amount required for the oxidation of a given substrate. Therefore, the ratio of synthesis to oxidation must be a constant for a given system." These workers reported that the oxidation of glucose goes approximately one-half to completion during the primary stage of assimilation.

Although Streeter and Phelps (9), in 1925, first concluded that the rate of biochemical oxidation of organic matter is proportional to the remaining concentration of unoxidized substance, it is apparent in his later publications that his confidence in this formulation was not complete. He repeatedly stressed the fact that there is no reason for the rate to follow an exponential function formulation (1). It is believed that if the above referenced works of Barker (7) and Clifton and Logan (8) had been available to Phelps at the time of preparation of his discussion of the biological stabilization of organic material, the anomalies listed therein would have been resolved and the fact of the two-stage reaction recognized. The emphasis in research switched from BOD to activated sludge in the early 1930's and did not return until about ten years ago, coincident with the advent of the present industrial waste age. Thus, Phelps' discussion was primarily based on data obtained prior to 1930.

Comments on Other Investigations

As long as the BOD test has been known as such, workers have decried the fact that five days are required to obtain results from a given analysis. The originators of the procedure attempted to shorten the time required but concluded that although a 24-hr test might be satisfactorily employed, the potential errors of technique made the short time undesirable.

In the last decade numerous articles have appeared in the literature reporting results of studies aimed at either delineation of the BOD reaction or the development of a short-term test, or both.

In 1948, Caldwell and Langelier (10) in a treatise on a manometric technique for the BOD determination pointed out the unsuitability of a 3-day incubation in the standard bottle procedure because of variations in results attributed to an erratic lag phase.

In 1948, also, Gotaas (11) published the results of BOD studies at various temperatures. His data show a break occurring after the first few days of incubation at 5° and 10°C, corresponding to the plateau noted herein. He pointed out that k values computed by ignoring this break conformed more closely to work of other investigators than did values taking the break into consideration.

Ingols (12), in 1949, reported on attempts to develop a short-time BOD test and concluded that "The use of a short-time BOD test is, even with a heavy inoculum, subject to much greater errors than the present 5-day incubation period because of the lag period in the bacterial activity." Although the individual points were not shown, Ingols' plotted data clearly indicate the characteristic plateau, particularly when a homogenized sewage was used.

In 1950, Sawyer *et al.* (6) published their work on establishment of primary standards for BOD work and emphasized the variations in results obtained with seed of different viability.

Also in 1950, Norgaard (13) recommended including a 1-day BOD test in routine analysis of wastes after noting that the 1-day BOD of a settled mixture of sewage and industrial wastes was consistently 60 per cent of the 5-day BOD during a three-month period. The 5-day values ranged from

620 to 1,230 mg/l on a monthly average basis.

Almost simultaneously with publication of Busch and Sawyer's work in 1952, Zehnpfennig and Nichols (14) presented data showing a 2-day BOD procedure to be more reproducible than the standard 5-day test in the analysis of sewage and pulp mill wastes and speculated that protozoa were responsible for the variations in 5-day results. However, no plotted data were shown.

In 1953, Orford and Ingram (15) concluded that not only is the monomolecular equation a poor expression for analysis of biological oxidation but that k and L vary with time and thus, ". . . have very little physical or biological significance as measures of oxidation speed or strength."

Also in 1953, Hoover *et al.* (2) reported that "The BOD test consists of two biochemical reactions—first, the rapid growth of cells with assimilation of available nutrients into the cells, and second, the subsequent slow endogenous respiration of those cells. The first stage is completed in a maximum of 24 hr; often it is completed before the sample is introduced into the BOD bottle." These authors' presentation called for a reassessment of the BOD test on the basis of their data showing, among other facts, that no soluble substrate remained in BOD samples after 24 hr of incubation. This work involved only milk wastes as substrate and the authors did not discuss the role of predators, as previously indicated.

Buswell *et al.* (16), in 1954, concluded that the monomolecular law is invalid for the BOD test and that current opinion supported this viewpoint. These authors agreed with the conclusions of Hoover *et al.* (2) but did not comment on protozoa either. Buswell (17) later pointed out that acceptance of the fact that the rate of oxygen absorption is dependent on numbers of bacteria, and not on the amount of oxidizable material present, marks the end of an era.

Tidwell and Sorrels (18) (19) have published results in support of Zehnpfennig and Nichols (14) but did not postulate a theory for the improved reproducibility of the 2-day test nor did they show plotted data.

These are a few of the published papers which lead inexorably to the conclusions reached by Barker (7), Clifton and Logan (8), and other microbiologists over 20 yr ago; i.e., that bacterial decomposition of organic substances is a two-stage process.

Need for a Reproducible Test

Typically evident of the need for a clear and definitive delineation of the progression of BOD in all types of wastes is a recent paper by Oberton and Stack (20). Their paper summarizes 22 years of work by one industrial organization to effectively measure waste pollutional characteristics, without notable success in the development of a specific determination. In most documented instances, investigators probably chose too long an incubation period for obtaining reproducible data. It should be recognized that the first stage assimilation value for different complex organics may range from 10 to 100 per cent of the theoretical oxygen demand. This conclusion is demonstrated by the work of Placak and Ruchhoft (21) reporting studies with activated sludge. That such data are directly comparable to BOD studies was effectively demonstrated by Hoover *et al.* (2). The only difference between activated sludge and BOD bottle studies of soluble substrates is concentration and hence time.

Monod (22) has proposed measurement of total bacterial growth patterns as a quantitative method for analysis of mixtures of carbohydrates. The distinct possibility of developing a valid short-term procedure for the evaluation of total load by measuring the

BOD through use of the plateau as a reference point is clear. Current research at The Rice Institute is concerned with the establishment of such a procedure.

Conclusions

The following conclusions may be drawn:

1. The progression in soluble substrates of BOD exerted by mixed cultures of sewage organisms seed is a multi-stage reaction.

2. The first stage represents conversion of available substrate into cell material plus intermediate stored products.

3. Any subsequent utilization of oxygen in excess of the endogenous rate is due to predator activity.

4. Utilization of the plateau in oxygen consumption corresponding to the first stage of bacterial decomposition as a reference point for BOD studies is theoretically valid.

Summary

A theory as to the progression of BOD in soluble substrates has been presented. Experimental data supporting the theory are shown. Results of other investigators have been shown to agree with the theory presented although in some instances the original conclusions were diametrically opposed. The theory offers a valid basis for establishment of a short-term BOD test.

Acknowledgments

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References

1. Phelps, E. B., "Stream Sanitation." John Wiley & Sons, Inc., New York, N. Y. (1944).
2. Hoover, S. R., Jasewicz, L., and Porges, N., "An Interpretation of the BOD Test in Terms of Endogenous Respiration of Bacteria." THIS JOURNAL, **25**, 10, 1163 (Oct. 1953).
3. Busch, A. W., and Sawyer, C. N., "Application of the Dropping Mercury Electrode to BOD Determinations." Unclassified A.E.C. Document, N.Y.O. 4436, Contract No. AT (30-1)-621 (1952).
4. Garrett, M. T., Jr., and Sawyer, C. N., "Kinetics of Removal of Soluble BOD by Activated Sludge." *Proc. 7th Ind. Waste Conf.*, Purdue Univ., 51 (1952).
5. Horton, J. P., Sc.D. Thesis, Massachusetts Institute of Technology (1952).
6. Sawyer, C. N., Callejas, P., Moore, M., and Tom, A. Q. Y., "Primary Standards for BOD Work." THIS JOURNAL, **22**, 1, 26 (Jan. 1950).
7. Barker, H. A., "The Oxidative Metabolism of the Colorless Alga, *Prototheca Zopfii*." *Jour. of Cellular Comp. Physiol.*, **8**, 231 (1936).
8. Clifton, C. E., and Logan, W. A., "On the Relation Between Assimilation and Respiration in Suspensions and in Cultures of *Escherichia Coli*." *Jour. of Bact.*, **37**, 523 (1939).
9. Streeter, H. W., and Phelps, E. B., Public Health Bulletin 146. U. S. Public Health Service, Washington, D. C. (1925).
10. Caldwell, D. H., and Langelier, W. F., "Manometric Measurement of the Biochemical Oxygen Demand of Sewage." *Sewage Works Jour.*, **20**, 2, 202 (Mar. 1948).
11. Gotaas, H. B., "Effect of Temperature on Biochemical Oxidation of Sewage." *Sewage Works Jour.*, **20**, 3, 441 (May 1948).
12. Ingols, R. S., "A Study of BOD with Time as the Measured Variable."

Sewage Works Jour., **21**, 6, 984 (Nov. 1949).

13. Norgaard, J. T., "Significant Characteristics of Sewage and Industrial Wastes" THIS JOURNAL, **22**, 8, 1024 (Aug. 1950).
14. Zehnpfennig, R., and Nichols, M. S., "Inoculation Studies in BOD Determinations of Sewage and Pulp Mill Wastes." THIS JOURNAL, **25**, 1, 61 (Jan. 1953).
15. Orford, H. E., and Ingram, W. T., "Deoxygenation of Sewage. I. Critical Review of the Monomolecular Formula." THIS JOURNAL, **25**, 4, 419 (Apr. 1953).
16. Buswell, A. M., Mueller, H. F., and Van Meter, I., "Bacteriological Explanation of Rate of Oxygen Consumption in the BOD Test." THIS JOURNAL, **26**, 3, 276 (Mar. 1954).
17. Buswell, A. M., "The BOD Test and Total Load." THIS JOURNAL, **27**, 11, 1297 (Nov. 1955).
18. Tidwell, W. L., and Sorrels, J. H., "Effect of Bacterial Flora on Deoxygenation." THIS JOURNAL, **27**, 2, 166 (Feb. 1955).
19. Tidwell, W. L., and Sorrels, J. H., "Comparative Evaluation of Special 2-Day and Standard 5-Day BOD Tests." THIS JOURNAL, **28**, 4, 488 (Apr. 1956).
20. Oberton, A. C. E., and Stack, V. T., Jr., "Biochemical Oxygen Demand of Organic Chemicals." THIS JOURNAL, **29**, 11, 1267 (Nov. 1957).
21. Placak, O. R., and Ruchhoft, C. C., "Studies of Sewage Purification. XVII. —The Utilization of Organic Substrates by Activated Sludge." *Sewage Works Jour.*, **19**, 3, 423 (May 1947).
22. Monod, J., *Ann. Rev. Microbiol.* (1949).

MEETINGS OF INTEREST

1958

Nov. 6–7 **Water Resources Conference,** State College of Washington, Pullman, Wash. William H. Knight, Technical Extension Services, Washington State Institute of Technology, Pullman, Wash.

Nov. 10–13 **American Petroleum Institute,** Palmer House and Congress Hotels, Chicago, Ill. American Petroleum Institute, 50 West 50th St., New York, N. Y.

Nov. 18–20 **National Air Pollution Conference,** Sheraton Park Hotel, Washington, D. C. The Surgeon General, Public Health Service, U. S. Department of Health, Education, and Welfare, Washington 25, D. C.

Nov. 30–Dec. 5 **American Society of Mechanical Engineers,** Statler and Sheraton-McAlpin Hotels, New York. American Society of Mechanical Engineers, 29 West 39th St., New York 18, N. Y.

Nov. 30–Dec. 3 **American Municipal Association,** Statler Hotel, Boston, Mass. Patrick Healy, Jr., Executive Director, 1313 East 60th St., Chicago 37, Ill.

Dec. 7–10 **American Institute of Chemical Engineers,** Netherland Plaza Hotel, Cincinnati, Ohio. F. J. Van Antwerpen, 25 West 45th St., New York 36, N. Y.

Dec. 12–13 **Fifth Annual Wastes Engineering Conference,** The University of Minnesota, Minneapolis, Minn. Director, Center for Continuation Study, University of Minnesota, Minneapolis 14, Minn.

SOLIDS CONTROL PROBLEMS IN ACTIVATED SLUDGE

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The problems of activated sludge loadings and operational techniques required to avail specific degrees of sewage purification, and the aspect of subsequent sludge increases necessitating quantative disposal, have been probed by many investigators (1)(2)(3)(4)(5)(6). Further, the enigmas of conditioning activated sludge so as to realize optimum settling characteristics without sacrificing maximum zoogleal adsorption, in particular, and metabolic processes, in general, have generated significant divergencies among some investigators (1)(2)(3)(7)(8).

Cursory observations at the Tucson activated sludge treatment plant suggested several of these divergencies and were responsible for the formulation of experiments involving activated sludge and its volatile solids content. Routine plant analyses indicated a generally lower and more stable sludge volume index when aerator liquor solids were not so high as those carried in previous years. Obviously, with other things being equal or relatively constant, to decrease mixed liquor solids would be equivalent to lowering the aerator solids to primary effluent solids ratio. The apparent mechanics of altering this ratio and its effect on the specific gravity of the sludge zooglea are discussed by Kraus (1) and supported by Heukelekian and Weisberg (7). However, above a rather obscure sludge loading factor some investigators prefer to modify the descriptive terminology applied to the process and substitute such terms as "aeration" or "bio-oxidation" (7). When contact periods are abbreviated and techniques of intensive reaeration or conditioning are employed—with or without additives—other trade names are in evidence (1)(6). All these processes, whether conventional or modified, have one inseparable requisite in common—the sludge must settle and leave a high quality supernatant.

Outline of Procedure

The purpose of this paper is not to delineate or distinguish any process or phase of operation, but rather to display the qualitative and quantitative impact of varying, by autogenous biochemical action, volatile solids and/or ash content of a given sample of activated sludge. A portion of the data is directed toward an appraisal of merit in carrying high mixed liquor solids in an activated sludge plant as opposed to a relatively low concentration, with volatile solid percentages regarded as significant variables. The balance of the data parallels this evaluation by examining the extent of dissipation, if any, of added volatile solids in activated sludge during prolonged biochemical action.

Experiment I deals with volatile solid changes over a 24-hr period, along with changes in general sludge conditions, and is divided into two parts—Schedule A maintaining high suspended solids, and Schedule B maintaining low suspended solids.

Experiment II deals with the build-up rate of suspended solids (sludge) when raw sewage is added to activated sludge liquor and no suspended solids are removed. The over-all dissipation of volatile solids was also considered.

Experiment I

Schedule A

The objective was to compare activated sludge liquor containing a relatively high quantity of suspended solids with that having a relatively low quantity of suspended solids, with equal feeding and aeration in each case.

The procedure was as follows. Into a 1-l graduated cylinder, 825 ml of return, concentrated activated sludge was placed and made up to 1 l with primary settling tank effluent. This liquor was thoroughly shaken and a Mohlman sludge volume index was run. The liquor was reshaken and an 80-ml sample was withdrawn for laboratory analysis. The remainder of the mixed liquor was aerated the following 19 hr (total of 24-hr aeration) and a 70-ml sample then withdrawn for analysis. At the end of this first day's period, 770 ml of liquor remained, or was brought up to this volume with distilled water. To this was added 40 ml of return, concentrated activated sludge and 190 ml of primary effluent. This was thoroughly mixed, and a sludge volume index determined. Thereafter, for a total of five days, the procedure was the same as that for the first day after the index was run. At the end of five days the remaining portion of liquor was merely aerated for another three days to note any changes.

TABLE I.—Changes in Volatile Solids and General Sludge Conditions in a Controlled Activated Sludge Carrying a Relatively High Amount of Suspended Solids *

Item	Days of Test					
	1	2	3	4	5	Avg
Mixed liquor total solids (%):						
At start:						
Volatile	72.18	71.62	77.41	81.58	79.64	
Ash	27.82	28.38	22.59	18.42	20.33	
5-hr aeration:						
Volatile	71.29	70.90	80.17	81.33	80.64	
Ash	28.71	29.10	19.83	18.67	19.36	
24-hr aeration:						
Volatile	71.00	76.34	83.68	81.45	—	
Ash	29.00	23.66	16.32	18.55	—	
48-hr aeration:						
Volatile	—	—	—	—	81.75	
Ash	—	—	—	—	18.25	
72-hr aeration:						
Volatile	—	—	—	—	80.14	
Ash	—	—	—	—	19.86	
Mixed liquor suspended solids (ppm):						
At start	5,420	4,287	3,227	2,583	2,231	
5-hr aeration	5,310	4,270	3,173	2,553	2,175	
24-hr aeration	5,340	3,967	3,083	2,520	—	
48-hr aeration	—	—	—	—	2,141	
72-hr aeration	—	—	—	—	2,127	
Primary effluent:						
Suspended solids (ppm)	63	54	75	76	76	69
BOD (ppm)	95	94	85	70	91	87
Sludge volume index	191	240	319	366	403	304
Per cent settled†	99.8	99.2	98.5	90	86	95

* Average of three runs.

† Average of two runs.

TABLE II.—Changes in Volatile Solids and General Sludge Conditions in a Controlled Activated Sludge Carrying a Relatively Low Amount of Suspended Solids *

Item	Days of Test					
	1	2	3	4	5	Avg
Mixed liquor total solids (%):						
At start:						
Volatile	71.41	72.51	69.99	71.67	71.84	
Ash	28.59	27.49	30.01	28.33	28.16	
5-hr aeration:						
Volatile	72.09	70.21	68.63	72.10	71.25	
Ash	27.91	29.79	31.37	27.90	28.75	
24-hr aeration:						
Volatile	71.89	70.52	71.72	71.23	—	
Ash	28.11	29.48	28.28	28.77	—	
48-hr aeration:						
Volatile	—	—	—	—	71.59	
Ash	—	—	—	—	28.41	
72-hr aeration:						
Volatile	—	—	—	—	74.65	
Ash	—	—	—	—	25.36	
Mixed liquor suspended solids (ppm):						
At start	1,537	1,416	1,315	1,272	1,193	
5-hr aeration	1,556	1,410	1,310	1,245	1,142	
24-hr aeration	1,507	1,364	1,277	1,202	—	
48-hr aeration	—	—	—	—	1,085	
72-hr aeration	—	—	—	—	1,058	
Primary effluent:						
Suspended solids (ppm)	71	70	61	68	84	71
BOD (ppm)	82	91	92	91	83	88
Sludge volume index	274	235	276	242	244	254
Per cent settled	42	33	36	30	29	34

* Average of three runs.

Schedule B

Schedule B is the same as A, with the exception that mixed liquor from the end of the aeration tanks is substituted for the return, activated sludge.

Experimental Comments

The 230 ml (total) taken for analysis represents 23 per cent "wasting" of the mixed liquor. However, since it is not secondary settled sludge, which would normally concentrate the solids five to eight times, the ratio of solids is about normal for conventional plant operation.

The return, concentrated sludge added during these periods averaged 7,000 ppm.

The aeration period of 24 hr represents approximately 300 per cent increase over normal aeration periods. The wasted volume is seven times as much; the aeration period is four times that in normal plant operation.

The air volume was constant—just enough to keep the liquor well in motion.

Evaporative losses were replenished with distilled water.

All samples analyzed for solids were ignited at 600°C for 15 min. Gooch crucibles were employed.

A decrease in solids from day to day was anticipated due to dilution, but any change within any one day was primarily the subject to be observed.

Results

Tables I and II include summaries of data from Schedules A and B, respectively. From these data the following results were observed:

1. Schedule B (relatively low suspended solids) gave more consistent results of a desirable nature than Schedule A (relatively high suspended solids).

2. Relatively high solids and low feeding gave poorer supernatant and sludge volume index than a more balanced feeding as in Schedule B.

3. Prolonged aeration, causing fluffy, low-density floc, occurred more noticeably in Schedule A than in B. This is related to No. 2, above.

4. Volatile matter was reduced more consistently when a proper air to suspended solids to waste ratio was maintained in the sludge liquor as demonstrated in Schedule B.

5. The almost linear increase in volatile matter during the second and third days of Schedule A suggests a predominant synthesis of microscopic and macroscopic zooglea. This did not occur to any extent in Schedule B.

6. A more stable sludge volume index was maintained in the experiment with low suspended solids.

7. A 3 to 5 per cent volumetric wasting of return, concentrated sludge was indicated as being desirable in Schedule B, more for Schedule A.

Generally speaking, Experiment I illustrates a definite volatilization and initial increase in ash when normal, primary effluent is added to healthy, well-aerated activated sludge. A ratio encouraging optimum biological activity seems to be in the range of 1 lb primary solids to 25 lb activated sludge solids. With this ratio most of the volatile solids deterioration is completed within the first six hours, which is a reasonable aerator detention time in many sewage treatment plants. A correlation is also suggested between ash content and sludge volume index.

Experiment II

In order to ascertain the degree of volatile matter disappearance Experiment II evolved. However, the more desirable ratio of 1 lb primary solids to 25 lb activated sludge solids, as noted in Experiment I, was replaced by one more nearly 1 lb primary solids to 3 lb activated sludge solids. This ratio change was initiated in order to counteract the tendencies of Schedule A, Experiment I, and to encourage logarithmic increases in numbers of biological organisms for maximum biochemical activity and minimum tendencies toward autolysis; also, because of the continual aeration no trouble was expected in relation to overloading the mixed liquor. By determining the initial weight of the liquor solids, the final weight of solids after aeration, and the weight of suspended solids added intermittently, it should be possible to calculate the theoretical increase in ppm as compared to the actual increase.

Objective and Procedure

Therefore, the objective was to determine the buildup rate of suspended solids and the breakdown of volatile materials in activated sludge when solids are added but none are withdrawn or wasted.

The procedure was as follows. A sample of activated sludge liquor (500 ml) was made up to 1 l with raw sewage and aeration was started. Five hours later a sludge index was determined, 300 ml of supernatant were siphoned off, and again the liquor was brought up to volume with raw sewage. At the end of 24 hr another sludge index was determined, 300 ml of supernatant removed, and the liquor replenished with sewage. Aeration was continuous except for those periods when a sludge index was being run and when

TABLE III.—Summary of Activated Sludge Test Showing Solids Balance of Suspended Solids with Controlled Amounts of Suspended Solids Added and No Wasting *

Days of Test	Mixed Liquor Susp. Solids (ppm)		Raw Sewage Susp. Solids (ppm)		Per Cent Settled (1,000 ml)		Sludge Index		Raw Sewage Added		
	5 hr Aer.	24 hr Aer.	5 hr Aer.	24 hr Aer.	5 hr Aer.	24 hr Aer.	5 hr Aer.	24 hr Aer.	Susp. Solids (g)	BOD (ppm)	Ash (%)
1	930	1,040	400	420	16	17	172	163	0.1680	255	16.17†
2	1,020	1,040	420	540	17	17	165	163	0.1121	209	24.91†
3	1,050	1,130	340	390	18	20	165	169	0.2512	178	25.15
4	1,140	1,230	390	460	20	24	167	183	0.3220	184	53.23
5	1,260	1,180‡	460	250‡	24	22‡	176	166‡	0.2348	179	25.58
6	1,210‡	1,240‡	250‡	320‡	21‡	22‡	158‡	166‡	0.2762	175	18.16‡
7	835†	1,420	320†	280	10†	26	120†	174	0.1482‡	162†	39.67‡
8	1,470	1,470	280	500	26	26	170	166	0.1428‡	—	—
9	1,520	1,550	500	290	26	26	159	154	0.1680	164‡	20.55
10	1,550	1,550	290	360	25	24	155	147	0.2980	192	35.09
11	1,600	1,700‡	360	440	24	25	144	123‡	0.1752	153	20.02
12	1,790†	—	740†	—	32†	—	179†	—	0.2136	262	25.91‡
13	—	—	—	—	—	—	—	—	0.2652	238	26.23
14	—	1,640‡	—	300‡	—	18‡	—	106‡	—	—	—
15	1,560‡	1,900†	—	—	26†	28†	114‡	147†	—	—	—

* Average of three runs.
† Data from one run.
‡ Average of two runs.

supernatant was being withdrawn. This procedure was to be repeated for two weeks.

The daily suspended solids were determined by use of a centrifuge plus conversion graphs; the initial and final samples were determined gravimetrically.

Results

Table III shows a summary of the data obtained from Experiment II, wherein a suspended solids balance was obtained with known amounts of added suspended solids to an activated sludge unit in which wasting of mixed liquor was not practiced. Table III shows the averages of three separate runs using the same procedure.

The solids balances for each run are given in Table IV. From these data it can be seen that, of the average of 3.2406 g of suspended solids aerated, there were 1.6620 g remaining at the end of the aeration period. Therefore, the average quantity of suspended solids biochemically oxidized amounted to 1.5786 g, or 48.71 per cent of the total fed. Also, as a matter of interest, the actual increase in suspended solids during the test was 156.2 per cent; whereas, according to the loading, the theoretical increase could have been 326.2 per cent. The volatile portion of the suspended solids added in the raw sewage amounted to 71.79 per cent.

As observed in other experiments, a wasting program correlated with sewage strength and air is essential to maintain the maximum adsorptive capacity of the activated sludge. By the end of five days the sludge, although still having a low index, began to sacrifice its ability to leave a clear supernatant on settling. However, in this case, the addition of a strong sewage sample and further aeration tended to remedy this condition. For the first week, although the solids materially increased, the volume occupied by the settled solids was almost constant.

TABLE IV.—Suspended Solids Balance for Experiment II

Initial Wt. Sludge Liquor Susp. Solids (g)	Final Wt. Sludge Liquor Susp. Solids (g)	Total Susp. Solids Aerated (g)	Total Susp. Solids Dissipated (%)	Actual Increase in Susp. Solids During 2-Week Period (%)	Theor. Max Increase in Susp. Solids During 2-Week Period (%)	Volatile Portion of Susp. Solids* (%)	Volatile Portion of Susp. Solids Actually Dissipated (g)	Volatile Portion of Susp. Solids Max Theor. Dissipated (g)
(*a*) Run No. 1								
0.6600	1.690	3.0540	44.66	163.5†	362.7	79.84	1.364	2.438
(*b*) Run No. 2								
0.6850	1.532	2.9456	47.99	141.7‡	330.0	68.49	1.4136	2.0174
(*c*) Run No. 3								
0.7650	1.765	3.7223	52.58	163.3§	386.6	67.04	1.9573	2.4954

* Difference between volatile solids of initial and final mixed liquor negligible.
† Supernatant suspended solids carry-over = 0.0492 g.
‡ Supernatant suspended solids carry-over = 0.1238 g.
§ Supernatant suspended solids carry-over = 0.2495 g.

Discussion

Unless a deep buffering blanket and/or a reserve of activated sludge is advantageous in the secondary clarifiers, there is little apparent logic in carrying relatively high aerator solids when a domestic, raw sewage of low or medium strength is involved. Both experiments indicated a noticeable deterioration in sludge quality in approximately five days if feeding and wasting were not balanced properly.

The optimum biochemical activity of a given sludge liquor with subsequent volatile solids reduction is maintained through definite ratios of introduced organic loadings to activated sludge concentration. A ratio suggested by these experiments is approximately 1 lb primary effluent suspended solids to 25 lb return activated sludge suspended solids. This should be commensurate with total sewage strength and other variables.

The primary effluent used in Experiment I averaged 70 ppm suspended solids and 88 ppm BOD. Further, it was indicated that with a return activated sludge carrying 7,000 to 10,000 ppm suspended solids a quantitative wasting of 3 to 5 per cent was required, and even more when aerator detention time is above normal and rate of air input is sufficient.

Five to six hours of thorough sludge liquor aeration produced a sparkling effluent on settling and gave a low sludge volume index. Greater aeration periods without greater additions of sewage solids produced a light, fluffy activated sludge with poorer settling qualities.

The ratios, concentrations, and degrees of wasting suggested by this work have been applied at the Tucson activated sludge treatment plant with gratifying results. Conceivably, then, an established plant with adequate design capacity, treating domestic sewage, should by application of similar experiments, be able to ascertain a basic ratio for plant operation. Increasing biochemical activity of activated sludge, and improving its physical nature, are in effect increasing plant capacity as well as plant efficiency.

Acknowledgment

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References

1. Kraus, L. S., "Dual Aeration as a Rugged Activated Sludge Process." THIS JOURNAL, **27**, 12, 1347 (Dec. 1955).
2. Kraus, L. S., "The Use of Digested Sludge and Digester Overflow to Control Bulking Activated Sludge." *Sewage Works Jour.*, **17**, 6, 1177 (Nov. 1945).
3. Kraus, L. S., "Digested Sludge—An Aid to the Activated Sludge Process." *Sewage Works Jour.*, **18**, 6, 1099 (Nov. 1946).
4. Arden, E., and Lockett, W. T., "Experiments on the Oxidation of Sewage Without the Aid of Filters." *Jour. Soc. Chem. Ind.* (May 30, 1914).
5. Garrett, M. T., Jr., "Hydraulic Control of Activated Sludge Growth Rate." THIS JOURNAL, **30**, 3, 253 (Mar. 1958).
6. Ullrich, A. H., and Smith, M. W., "The Biosorption Process of Sewage and Waste Treatment." THIS JOURNAL, **23**, 10, 1248 (Oct. 1951).
7. Heukelekian, H., and Weisberg, E., "Bound Water and Activated Sludge Bulking." THIS JOURNAL, **28**, 4, 558 (Apr. 1956).
8. McKinney, R. E., and Gram, A., "Protozoa and Activated Sludge." THIS JOURNAL, **28**, 10, 1219 (Oct. 1956).

THE SIGNIFICANCE OF DETENTION IN SEDIMENTATION—DISCUSSION

I. OVERFLOW RATE CONCEPTS

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In the suggestive and interesting paper, "The Significance of Detention in Sedimentation," by E. B. Fitch (1), suspended solids are divided into two classes. Class I particles always remain discrete, while Class II particles coagulate or flocculate during the settling period. The paper presents theoretical and experimental evidence indicating that for Class II suspensions, time can be of considerably greater significance than overflow rate in the matter of sedimentation. In a contemporary paper by Budd (2), the same is stated to be true for the water familiar to the sanitary engineer, i.e., sewage and, assumedly, precipitated surface waters.

The question discussed—overflow rate versus time as the controlling factor (both cannot have this role)—is of paramount importance in the design of more economical, space-saving, and efficient sedimentation basins. Since the writer arrives at conclusions based on theory and practice that differ from those presented in the original paper, comment on the contradiction seems appropriate.

Definitions

To begin this discussion some redefining appears to be in order. The first deals with the properties of Class II suspensions. Several circumstances indicate that dominance of either time or overflow rate is not true for the whole of Class II. In other words, Class II seems too wide a concept. Perhaps there should be a Class II A, covering conditioned liquids where flocculation in sedimentation, if it occurs, is purely mechanical, and a Class II B, covering unconditioned liquids where electrical or chemical and perhaps, also, biological action is involved.

The second definition deals with the concept of sedimentation. Mr. Fitch begins his paper with the statement that the literature asserts sedimentation is always governed by overflow rate and "not at all" by detention time. It is the opinion in this discussion that assertions of this sort can be made only for the case of free settling when the presumptions made by Hazen (3) are fulfilled. For if the sedimentation basin also acts as a reaction tank, especially without the necessary turbulence, time can dominate. About 40 years ago, before the acceptance of the flocculation basin, all "precipitation basin" efficiencies were dependent on time. Then, baffles causing turbulence also increased the "sedimentation" efficiency. The laws to be used depend on the meaning of sedimentation. Geologists understand natural sedimentation as all processes causing particles to settle. In the water purification technique words with an unmistakable sense would be preferable. Perhaps "free settling" or "plain sedimentation," "hindered settling" or "thickening," would do.

Short-Circuiting

In discussing the theory Mr. Fitch cites two assertions by Camp (4), the first implying that removal "is unaf-

fected by depth except through influence of turbulence and bottom scour" and the second that "short-circuiting decreases removals." He later says that for Class I particles it has been shown (5) that removal "is not at all affected by density-current short-circuiting." Camp's second assertion is said to be not generally true.

Short-circuiting in the vertical plane need not cause disturbance in the settling process. The overflow rate is not altered, and if turbulence and bottom velocity are not harmful for the actual suspended matter, then efficiency should be practically unaffected. It is even possible that a non-uniform velocity, e.g., the natural undisturbed velocity distribution, or a surface flow, is superior to ideal flow because bottom velocity is then decreased (5). This latter case was discussed by Hazen in Proposition 10 (3).

Short-circuiting in the horizontal plane affects the overflow rate so that part of the liquid will have an increased rate and part a decreased rate. Under very special circumstances this can lead to improved sedimentation (6).

The effect of short-circuiting depends on its magnitude in relation to the quality of the suspended matter. Fine sediment, such as Mr. Fitch experimented with, is extremely sensitive, while coarse matter, such as grit and sand, is unaffected even by strong irregularities in the flow. Consequently, short-circuiting does not always cause decreased sedimentation efficiency. The settling properties of a basin are, however, always of a lower class in a basin with pronounced short-circuiting than in a basin with undisturbed flow.

Overflow Rate and Detention

In general, the writer agrees in the above respect with Mr. Fitch. But, when discussing Eliassen's tanks (7) the writer does not believe the overflow rate in Tank A can be calculated to be one-third of the overflow rate in Tank B. The settling depth of Tank A cannot be three times that of B, because the lower two-thirds of the depth in A is stagnant water, and the top of that layer must be the theoretical bottom of the tank. Or in another way, the overflow rate, h/t, shown in Eq. 3 (1), when used for calculation of the overflow rate of a basin with uneven water distribution, as in Tank A, will be,

$$\int \frac{h}{t} = \Sigma \frac{h}{t} = \frac{h_1}{t_1} + \frac{h_2}{t_2} + \cdots + \frac{h_n}{t_n}$$

in which h and t represent depth and detention time, respectively, for sections of the tank with different velocities. In Tank A,

$$t_2 = \infty$$

hence,

$$\frac{h_2}{t_2} = 0$$

and the effective depth is h_1. The simple formula, h/t, as used in the original paper (1) does not take into account the effect of the non-uniform flow. Further, its use would indicate that the overflow rate increases with an increase in short-circuiting, but Hazen's Proposition 10 (3) does not show this to be so. In view of this the conclusions drawn do not appear valid. Neither is it likely that the conclusion drawn from Camp's Assertion II would be true because increased detention time will no doubt further decrease stability and impair efficiency. On the contrary, reduced detention time can be expected to improve settling efficiency (6).

Perhaps the most important question is whether (mechanical) flocculation is dependent on the time (depth) or not. In comparing a shallow and deep tank of equal surface area Mr. Fitch states: "Assuming identical concentration in the two cases, the probability that particle A will overtake and collide with some particle B is proportional to the volume swept by A. Therefore at a given overflow rate the

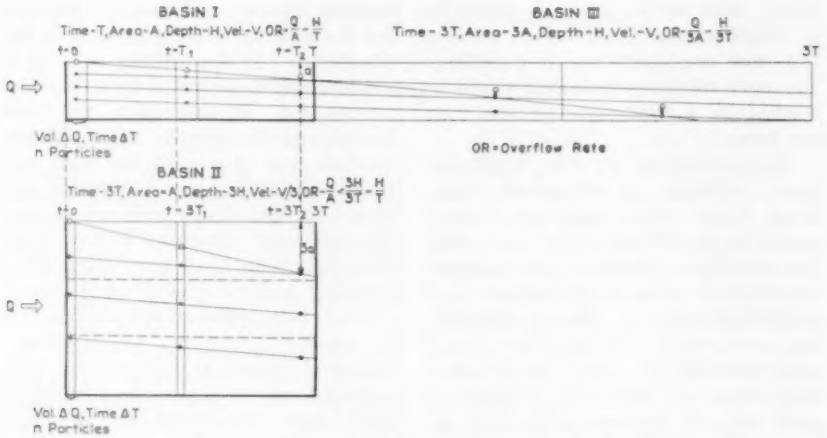

FIGURE 1.—Comparison of three sedimentation basins.

probability of collision must be proportional to tank depth and hence to detention time."

In Figure 1 of this discussion two basins are shown. One has three times the detention time of the other. Both have the same area, A, and the same load, Q. The liquid, ΔQ, entering the basins during the time increment, ΔT, has, in both basins, the same concentration and, consequently, the same number of particles. Assume the particle distribution comprises one coarse and three fine particles. These volumes travel in both basins unmixed with the surrounding water (ideal flow), and with the same number of particles and collisions at the same distance from the inlet. The depth will have no influence on each such volume of water travelling through the basin. The circumstance that the liquid enters with the same concentration of particles in both basins distributed over the entire depth has, in the example chosen, no influence in respect to the number of collisions per hour. The circumstance that there is three times the volume of water in "action" in the big basin is counterbalanced by the fact that this action takes a correspondingly longer time, 3 hr.

A threefold lengthening of Basin I creates Basin III, which has a 3-hr detention period, the same as for Basin II. However, increased efficiency will result because the overflow rate is now only one-third as high as the rate in the deep basin and three times as many collisions will occur, independent of the detention time. As an illustration, data from the tests found in Figure 6 of the original paper may be used, even if, perhaps, these tests were made on Class II B suspensions. Extrapolation yields the following:

Detention (hr)	Overflow Rate (ft/hr)	Sedimentation Efficiency (%)	Residual (%)
3	3.0	88	12
3	1.0	95	5

Reducing the overflow rate by two-thirds reduces the residual by approximately two-thirds and the run of a rapid sand filter, for example, would increase about 300 per cent. This result can also be acquired by increasing the settling time to about 4.5 hr, i.e., the volume by 50 per cent, or by inserting two trays. So, even with this suspension the increase in detention time can be made in different profitable

ways. Still better, possibly, would be to condition the liquid before settling and then use short-time free settling. The same efficiency probably would be reached in a total time of less than one hour.

The conclusions by Mr. Fitch are based entirely on laboratory tests. Even under these conditions experimentation is difficult. First, in a very fine suspension, the top of the compression zone is hard to distinguish and sampling is difficult. Second, the tube-test gives results valid only for a basin with full stability. In a basin with a long detention time the stability is poor and will decrease with time unless the hydraulic conditions are corrected. These corrections are often difficult and expensive.

Conclusions

From laboratory tests with two different suspensions, one involving "hindered settling" and the other chemical coagulation, Mr. Fitch has pointed to the influence of time in settling of all Class II suspensions. The writer has not found sufficient support in theory or practice to extend this conclusion to settling processes involving only pure mechanical agglomeration and doubts whether time is the only factor in settling Class IIB suspensions.

If during settling the number of collisions is affected by some factors, the settling velocity also will be influenced by these factors and the free settling process may be calculated from the overflow rate when the correct formula for the settling velocity is used in the calculation. If the settling velocity is continuously accelerated by a chemical process, e.g., crystallization, the same is true and the velocity will no doubt increase not only with the time but also with turbulence, concentration, etc. Stones (8) has shown with raw sewage that efficiency increases with settling time (treatment?) at least up to 8 hr, probably because of biological action. A much more efficient purification can be obtained, however, by short-time biological treatment followed by true settling for a short time in a multiple-story basin. The writer is of the opinion that time is not the only controlling factor in such a "settling" process. Therefore, the time formula is not a sound basis for further research and development because it does not truly represent what actually takes place.

During the past 10 years the writer has observed much progress in settling Class II A suspensions in basins designed on the overflow rate and the controlled flow theories (6). The load per unit volume has increased two to five times, i.e., detention time has decreased two to five times. Moreover, efficiency has increased and deviations have been minimized. Good performances have been obtained in treating surface and ground waters for public and industrial use and sewage. In the latter case both shallow one-story and multiple-story basins have been successful.

References

1. Fitch, E. B., "The Significance of Detention in Sedimentation." THIS JOURNAL, **29**, 10, 1123 (Oct. 1957).
2. Budd, W. E., "New Concepts of Sedimentation." *Public Works*, **88**, 12, 96 (Dec. 1957).
3. Hazen, A., "On Sedimentation." *Trans. Amer. Soc. Civil Eng.*, **53**, 45 (1904).
4. Camp, T. R., "Sedimentation and the Design of Settling Tanks." *Trans. Amer. Soc. Civil Eng.*, **111**, 895 (1946).
5. Fitch, E. B., "Flow Path Effect on Sedimentation." THIS JOURNAL, **28**, 1, 1 (Jan. 1956).
6. Fischerström, N. C. H., "Sedimentation in Rectangular Basins." *Proc. Amer. Soc. Civil Eng.*, **81**, (Sep. No. 687) (May 1955).
7. Eliassen, R., "Sedimentation and the Design of Settling Tanks—Discussion." *Trans. Amer. Soc. Civil Eng.*, **111**, 947 (1946).
8. Stones, T., "The Settlement of Sewage." *Jour. and Proc., Inst. Sew. Purif.*, Part 4, 349 (1956).

II. DETENTION TIME CONCEPTS

By E. B. Fitch

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The writer is grateful to Mr. Fischerström for his discussion. In submitting a paper (1) on what seemed to be a controversial subject, supporting a position in some cases directly opposed to that held by the most respected experts in the field, considerable comment and criticism were anticipated. It was hoped that in this way misunderstandings could be cleared away, facts more closely defined, and errors, wherever they existed, could be recognized and eliminated.

Definitions

Mr. Fischerström's first concern is with the broadness of Class II in clarification. It arises, it is believed, because in "long tube test No. 2" a chemical coagulant was added. He suggests that this represents a separate case, with different flocculation kinetics, and should be set up as a separate class. The point is well taken, and in any detailed study of flocculation kinetics it will probably be advisable to distinguish between "coagulation" on one hand and "mechanical flocculation" on the other. For this reason it is perhaps unfortunate that "long tube test No. 2" was selected for demonstration. However, "long tube test No. 1" described in the paper (1), and a great number of others, have been made on "mechanically" flocculating pulps without added coagulant. These give the same sort of experimental results as "long tube test No. 2," and likewise lead to the conclusion that removal is a function of detention time as well as of overflow rate (see Figure 6 of the original paper).

Within the context of the paper only, "clarification," or discrete particulate sedimentation, is considered as opposed to consolidated or zone settling on one hand, and compaction or compression on the other hand. The separation of "clarification" into two classes is largely a matter of convenience, since there is no discontinuity in behavior to create a natural division between the two classes. Class I has been defined to include suspensions in which the particles do not change significantly during the settling period, and hence, according to the findings of Hazen and many others, are not affected by detention *per se* in a sedimentation basin. Class II comprises suspensions in which the particles flocculate and hence change in settling characteristics during the sedimentation period.

Overflow Rate and Detention

It is not the writer's finding that either overflow rate or detention time will always be the dominating or controlling factor in Class II clarification. The experiments show that both are operating, and that they interact. When settling of individual particles proceeds very slowly, as compared to the rate of formation and settlement of floccules, then detention time is expected to have a large effect. On the other hand where settling of the individual particles is rapid relative to flocculation, Class I behavior is approached and overflow rate becomes the dominating factor. The important thing is that both are factors in Class II suspensions, and detention can possibly be of great importance. Therefore it is logical to take detention into account, rather than to design on the basis of overflow rate alone.

In Eliassen's (2) demonstration the writer would agree that the top of the stagnant layer in Tank A could be considered the "theoretical bottom of the tank" but not that it must be so considered. First, the particles must settle through this stagnant layer to be

removed, and hence it is almost tautology to say that this is part of their "settling depth." Second, if at the start conditions of no short-circuiting (Tank C) exist in Tank A and if the flow across the top third is gradually increased at the expense of the lower two-thirds, then clearly at first, the tank will be short-circuiting for the full depth. As the short-circuiting is increased the condition of no flow through the bottom two-thirds is approached with the "theoretical" tank bottom remaining at its actual bottom. There is no reason for a discontinuity in sedimentation behavior just at the instant the bottom flow becomes zero and hence the bottom two-thirds become stagnant. The settling depth can validly be considered to remain what it was throughout the process—the full depth of the tank. The logic of Eliassen's demonstration in this matter seems cogent and inescapable.

It is necessary to make clear distinction between tank volume and flow detention. An "unstable" tank of greater depth may give a lower effective detention than a shallower tank of better design. If Tank A short-circuited the upper one-fourth of its depth, then the flow would have a lower detention than shallower Tank B. When Mr. Fischerström emphasizes the "stability conditions" he appears to be dealing with the efficiency of the tanks in providing the detention necessary for the flocculation reaction.

In his demonstration of mechanical flocculation, Mr. Fischerström starts with the same tacit assumption as Camp (3), and with correct reasoning would have to arrive at the same conclusions. It is the assumptions which seem not valid. Thus, in each of his basins Mr. Fischerström shows an overtaking particle and three other particles lined up below it in such a manner that if the overtaking particle settled to the bottom of the flow, it must collide with each of the three. There is nothing but chance to cause such an alignment of particles. If it is assumed that the volume ΔQ contains these four particles, they may be distributed anywhere in the volume, and it is highly unlikely that the four would be lined up as indicated. The chance that an overtaking particle will find another particle lined up beneath it is (approximately) inversely proportional to the plan area of the volume ΔQ. The plan area of ΔQ in Basin II is one-third that of Basin I. Therefore the overtaking particle is approximately three times as likely to collide in Basin II as it is in Basin I. If an overtaking particle is three times as likely to collide with a slower particle, then in a swarm of slower particles it will hit three times as many—which is directly proportional to detention time.

Another way of showing the inconsistency is this: In suspensions of uniform concentration there must be the same average distance between particles measured in all directions. The particles in Basin II are three times as far apart vertically as they are in Basin I, and since there are the same number of particles per unit volume, they must be one-third as far apart horizontally. Such a distribution seems very unlikely.

If just the plan area within which the overtaking particles can contact an overtaken one is considered, it is found that it will be a circle with a diameter of two times that of the overtaken particle plus the diameter of the overtaking one. Any overtaken particle totally within this area will be contacted regardless of the shape of the basin. If particles are initially uniformly distributed, the number contacted by the overtaking particle will be proportional to the volume it sweeps. The volume swept by the overtaking particle will be the area of the above circle times the distance settled. The distance settled is proportional to time. Therefore the number of particles contacted by any overtaking particle will be proportional to detention time.

Conclusions

Careful analysis thus seems to indicate that the demonstration of "mechanical" flocculation presented by Mr. Fischerström rests on invalid assumptions. It is believed correction of these assumptions would lead to the conclusions of the paper. However, whatever the theoretical argument, it does not transcend the experimental results cited.

The writer agrees with Mr. Fischerström that the batch test results cannot be applied to full-scale continuous basins without proper allowance for the hydraulic behavior of the full-scale basin. It is precisely because the hydraulic characteristics of full-scale basins introduce variables difficult to control and evaluate that a batch test was designed and interpreted as a critical experiment to determine the role of detention in sedimentation.

References

1. Fitch, E. B., "The Significance of Detention in Sedimentation." THIS JOURNAL, **29**, 10, 1123 (Oct. 1957).
2. Eliassen, R., "Sedimentation and the Design of Settling Tanks—Discussion." *Trans. Amer. Soc. Civil Eng.*, **111**, 947 (1946).
3. Camp, T. R., "Sedimentation and the Design of Settling Tanks." *Trans. Amer. Soc. Civil Eng.*, **111**, 895 (1946).

SLIME LITERATURE REVIEW—ADDENDUM

The following supplementary list makes the Additional References current for the paper, "Slime Infestation—Literature Review. I. *Sphaerotilus*. II. *Leptomitus*. III. Summary and Conclusions," by M. E. Harrison and H. Heukelekian (THIS JOURNAL, **30**, 10, 1278 (Oct. 1958)):

Drescher, R. F., "Performance of Paper Machine Wet Felts. IV. Role of Iron Bacteria in the Plugging of Felts." *Tappi*, **40**, 11, 904 (1957).

Höhnl, G., "The Physiology of Iron Bacteria." *Water Poll. Abs.* (Brit.), **30**, 6, 192 (1957); *Vom Wasser*, **22**, 176 (1955).

Höhnl, G., "Biology of Waste Water Fungi, with Special Reference to Pulp and Paper Mill Effluents." *Wochbl. Papierfabrik*, **84**, 564 (1956); *Chem. Abs.*, **51**, 17163e (1957).

Pooth, I. S., "*Achlya prolifera* as Sewage Fungus in a Stream of Central Sweden." Inst. Fresh Water Research, Drottningholm, Rept. No. 38, p. 247 (1957); *Water Poll. Abs.*, **31**, 4, 898 (Apr. 1958).

Scheuring, L., "Biology and Metabolism of *Sphaerotilus natans*." *Arch. Hydrobiol.*, Suppl. XXII, 498 (1955); *Water Poll. Abs.*, **30**, 1, 12 (Jan. 1957).

Scheuring, L., and Höhnl, G., "*Sphaerotilus natans*, Its Ecology and Physiology." *Schrif. des Vereins der Zellstoff und Papier-Chemiker und Ingenieure*, **26**, 1 (1956).

Skerman, V. B. D., *et al.*, "Intra-cellular Deposition of Sulphur by *Sphaerotilus natans*." *Jour. Bact.*, **73**, 4, 504 (Apr. 1957).

Wolfe, R. S., "Cultivation, Morphology and Classification of Iron Bacteria." *Jour. Amer. Water Works Assn.*, **50**, 9, 1241 (1958).

Wurtz, A., "Fungi, Bacteria and Algae of Polluted Waters." *Bull. Franc. de Pisciculture*, **182**, 5; **184**, 89 (Sept. 30, 1956 and Mar. 31, 1957); *Pub. Health Eng. Abs.*, **38**, 7, 563 (July 1958).

SLUDGE DEWATERING PRACTICE *

By Eugene H. Trubnick and Peter K. Mueller †

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Mechanical sludge dewatering is finding application in an increasing number of sewage treatment plants because of the many inherent advantages which have made vacuum filtration an attractive process for sewage and industrial waste treatment. Among the principal advantages are:

1. Plant area requirements are greatly reduced when a small sludge dewatering building is substituted for drying beds or lagoons.
2. Mechanical dewatering can be placed on a routine schedule, coordinated with the rest of the plant, and unaffected by weather conditions.
3. Improved plant operation is permitted, and a greater degree of flexibility in operation is afforded.
4. Digester requirements may be reduced, since capacity need not be designed into them for winter storage, or it is possible that digesters may be eliminated entirely with the dewatering of fresh sludge.

Substantial progress has been made in the field of sewage sludge filtration since the first application of this process at Milwaukee in 1925. For the most part this progress has resulted from the contributions of operators in the field, on the basis of experiences at the various vacuum filter installations at sewage plants; only recently have university-sponsored studies made important contributions to the technology of sewage sludge filtration.

* Presented at the 42nd Annual Meeting, New Jersey Sewage and Industrial Wastes Assn.; Atlantic City, N. J., Mar. 13–15, 1957. This paper has been revised in the interim to include more recent data.

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Sludge Filterability

Accurate determination of the filterability of a sludge, as well as translation of experimental results to full-scale operation, have been quite difficult. Experimental tools, such as the Buchner funnel test and the filter leaf test, have limited application, and can be used only for establishing empirical relationships. This does not mean that the Buchner funnel and the filter leaf are not useful tools. But with neither of these is it possible to establish parameters independent of nearly all variables, which could be used in comparing sludges or in quantitatively evaluating the effects of significant forces on a given sludge. Such a parameter has been suggested by Coackley and Jones (1), who have used the concept of specific resistance of Carman's (2) theory of filtration. Specific resistance is defined as the resistance of a unit weight of filter cake per unit area at a given pressure. The mechanics of the specific resistance test are similar to those of the Buchner funnel test, with the exception that measurements are made of the filtrate volumes delivered at various time intervals during the filtration, rather than of the time required for a vacuum break. It was stated that the values for specific resistance of a sludge could be reproduced with an accuracy of ± 2 per cent, a far more impressive reproducibility than can be achieved with the Buchner test.

Coackley and Jones used specific resistance to study the effect of solids content and chemical conditioning on sludge filterability. In a later work Jones (3) used the specific resistance concept to predict full-scale results

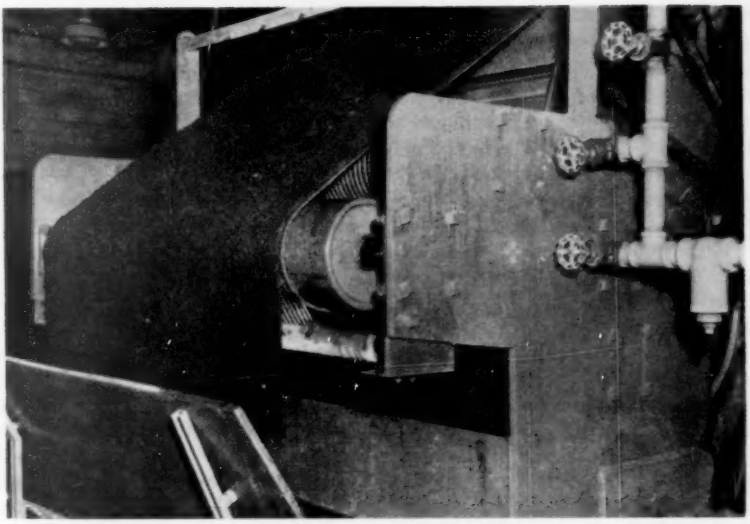

FIGURE 1.—Fibrous fresh sludge discharges from vacuum filter in continuous blanket.

from laboratory determinations, studying the effect of initial sludge moisture, pressure, and time of revolution in vacuum filters, or pressing time in pressure filters. The specific resistance test offers the promise of a systematic means of studying sludge filtration.

Filter production, or the results that can be attained, depend on three general factors:

1. The filter media, which is a characteristic of the equipment used.
2. The characteristics of the sludge.
3. Treatment of the sludge prior to dewatering—both chemical and physical.

Filter Media

The ideal filter media is one which offers no resistance to the flow of liquid. Woven cloth media, which were the earliest types used in sludge filtration, produced excellent results when new; but after very few hours of operation they became clogged with the finer sludge particles and with conditioning chemicals, thus offering greatly increased resistance to liquid flow. This increased resistance resulted in lowered yields.

The use of permanent non-clogging filter media has to a great extent eliminated media resistance as a factor in the filtration of sludge, and has thus focused attention on the inherent sludge characteristics and on sludge treatment as factors that affect filter yield, efficiency, etc. The non-clogging media have contributed to higher filter yields, and have made the vacuum filtration of fresh sludge feasible. Figure 1 shows a sludge blanket being discharged from such a filter.

Sludge Characteristics

Among the characteristics of a sludge which affect filtration are:

1. Size, shape, and charge of the solid particles.
2. Compressibility of solid particles.
3. Viscosity of filtrate and of sludge.
4. Chemical composition.
5. Solids concentration, dissolved and suspended.

Solid Particles

The size, shape, and density of the solid particles of a sludge affect filterability by virtue of the role they play in compaction and in requirements of coagulating chemicals. Irregularly shaped and sized, or small particles tend to form a compact mat under vacuum, leaving a small ratio of voids for migration of liquid. Regularly shaped and sized, or large particles, on the other hand, allow for a high ratio of voids. It has been shown (4) that the smallest particles of the sludge exercise the greatest coagulating chemical demand per unit weight of solids. Garber (5) found that the particle size of elutriated sludge after thermophilic digestion was greater than after mesophilic digestion. Wet screen analysis showed that 80 per cent of the solids in the mesophilic sludge passed a 200-mesh screen, while 65 per cent of the solids in thermophilic sludge were small enough to pass a 200-mesh screen. Digestion at the higher temperatures at the Hyperion plant resulted in a three-fold increase in filter yield with a 50 per cent reduction in coagulant demand.

In the light of available knowledge of the role of particle charges and their neutralization in coagulation, it is to be expected that these data may shed some light on the mechanics of filtration and the part played by chemical conditioning.

Compressibility

Particles of compressible sludges tend to deform as pressure increases and the result is a lighter filter cake. For a given sludge, compressibility can be expressed as a constant function of pressure. When the factor of compressibility is 1.0 it means that the filtration rate will remain the same when the filtration pressure is increased. Published information (3) (6) indicates that most sewage sludges treated with ferric chloride have a compressibility of 0.85 or more.

Viscosity

Viscosity of the filtrate is of academic interest in the filtration of sewage sludges, since filtrate viscosities do not vary significantly.

Chemical Composition

The chemical composition of the sludge to a great extent controls the amount of chemical required for conditioning. Genter (7) has shown that at least two factors have to be considered. These are: (a) the substances dissolved in the sludge water, specifically the bicarbonate alkalinity, and (b) the composition of the suspended solids, specifically the ratio of volatile matter to ash. The greater the alkalinity, the greater is the chemical demand; and the greater the amount of volatile matter, the greater is the chemical requirement.

Concentration

The fact that an increase in concentration produces an increase in cake production has long been known. Schepman and Cornell (8) have recently shown experimentally that the relationship of feed concentration to filter rate is linear and in some cases in direct proportion. This phenomenon is readily understandable when viewed from the standpoint that with more concentrated sludges less filtrate volume has to be removed per pound of filter cake deposited.

Sludges may be concentrated prior to dewatering by several methods. Secondary digesters may be considered sludge thickeners by virtue of providing a means of quiescent settling and also by allowing thorough release of gases adhering to the sludge particles. Elutriation, in addition to removing bicarbonates and lowering coagulant demand, frequently effects a concentration of digested sludge solids. Torpey and Lang (9) successfully employed elutriation for the sole purpose of thickening digested sludge from a modified activated sludge plant, more

than doubling the solids concentration from 2.5 to 5.9 per cent. Mechanical thickening either by slow agitation with, for instance, revolving rakes equipped with picket arms, or by aeration, is an effective means of concentrating either fresh or digested sludge. Flotation is also used as a means of thickening sludge.

Filtration Rates

Most of the sludge characteristics that determine filterability vary with the source of the sludge, so that the various processes of sewage treatment produce sludges of varying filterability. Table I is a tabulation of minimum filter rates attainable with various types of sludge on a nonclogging filter media.

TABLE I.—Minimum Filter Rates After Chemical Conditioning

Type of Sludge	Filter Rate (psf/hr)	
	Fresh	Digested
Primary	8	7
Primary & trickling filter	7	6
Primary & activated	6	5
Activated or trickling filter*	3	—

* Thickened to at least 3 per cent solids.

It is seen that in general fresh sludges are more filterable after chemical conditioning than digested sludges, and primary sludge is more filterable than secondary sludge. The relationships between filterability of fresh and digested sludges are readily understandable in view of the physical changes that occur during digestion. Fibers and particulate matter in fresh sludge, especially in primary sludge, are believed to be destroyed with the production of soluble, colloidal, and pseudo-colloidal matter. The resulting finer particles tend to fill the voids in the mat of a filter cake, and thereby interfere with filtration.

Fresh Sludge Filtration

Much attention is currently being focused on the dewatering of fresh sludge. The first vacuum filter installation in this country, put into operation at Milwaukee in 1925, was designed for dewatering undigested waste activated sludge for use as a fertilizer; in 1935, Perth Amboy, New Jersey, and Dearborn, Michigan, instituted vacuum filtration of fresh primary sludge. Today there are in this country at least 57 plants in operation, with 24 more under construction, where fresh primary and/or secondary sludge is being dewatered on vacuum filters. Subsequent disposal is either by incineration or by fill, or, in some

TABLE II.—Effect of Filtrate on Primary Effluent

Treatment Plant	Suspended Solids (ppm)				BOD (ppm)			
	Not Filtering		Filter Operating		Not Filtering		Filter Operating	
	Raw	Prim. Effl.	Raw	Prim. Effl.	Raw	Prim. Effl.	Raw	Prim. Effl.
Woodbridge, N. J.*	204	70	276	74	78	60	131	71
St. Charles, Ill.†	245	134	286	164	146	119	160	119
Conshohocken, Pa.‡	212	104	187	100	311	210	232	157
Wyomissing, Pa.§	146	90	172	100	233	148	265	162

* Fresh primary sludge.
† Fresh primary and secondary sludge from trickling filter plant.
‡ Digested primary and secondary sludge from activated sludge plant.
§ Digested primary and secondary sludge from trickling filter plant.

cases, by incorporation into the soil as a conditioner.

The economic advantages of fresh sludge dewatering (10) have been pointed out showing the savings that can be realized in capital expenditures for this type of plant as compared to the cost of a plant with digesters and sand beds.

Successful filtration of fresh sludge is dependent on the maintenance of an open filter media. Upon changing to an open mesh cloth at Minneapolis-St. Paul, filter production levels were maintained while tonnage of chemicals used for conditioning was greatly reduced (11).

An open mesh allows for a greater passage of solids into the filtrate. At Minneapolis-St. Paul the filtrate contains an average of 2,000 ppm suspended solids. The higher solids content of the filtrate, which might be considered as necessary for faster filtration, has no significant effect on the treatment processes when the filtrate is returned to the primary end of the plant. The data in Table II, collected from various sewage plants over periods ranging from one week to seven months, show that the filtrate has no significant effect on the efficiency of primary sedimentation tanks, either from the standpoint of suspended solids removal or BOD removal.

This absence of interference with the treatment process as a result of returned filtrate solids is readily understood in light of the fact that the solids have been conditioned and have thereby been rendered readily settleable. Figure 2 shows that the solids are almost completely removed within 10 min of quiescent settling.

Potential odors that might emanate from fresh sludge during filtration can be completely controlled by adding the lime prior to exposure of the

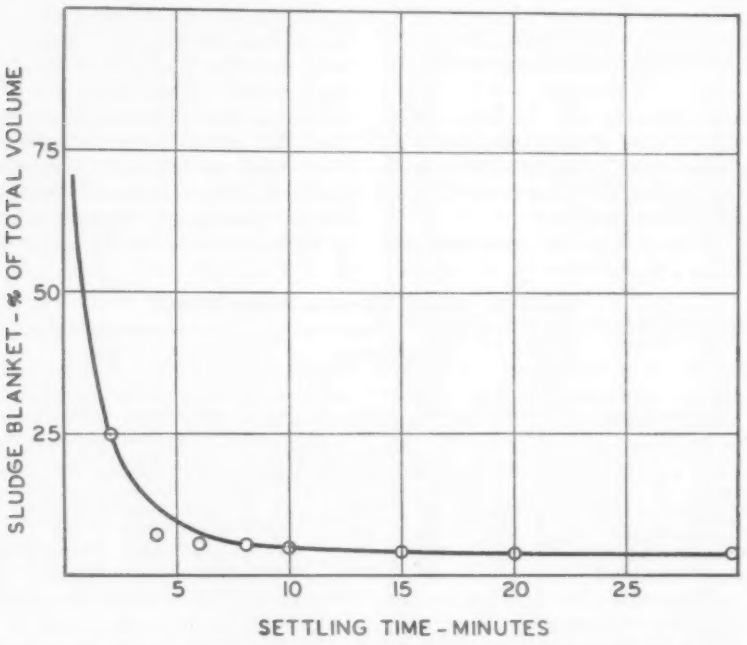

FIGURE 2.—Settling rate of filtrate solids, using elutriated digested primary sludge. Filtrate contained 750 ppm suspended solids.

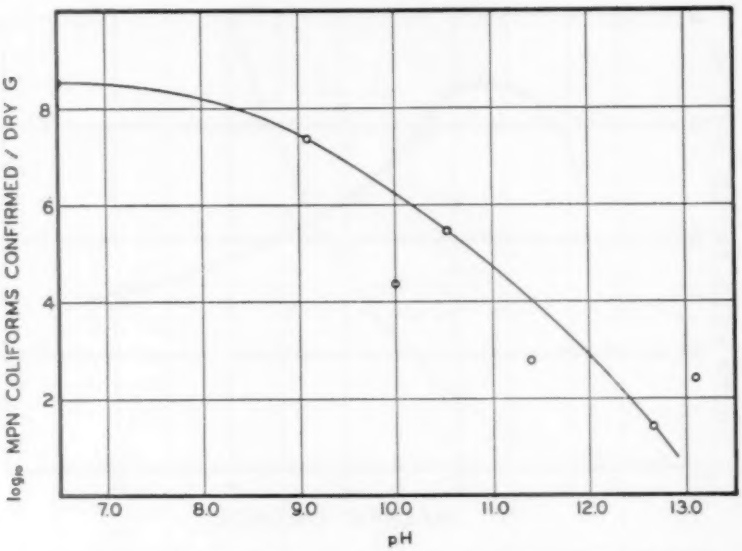

FIGURE 3.—Effect of pH on coliform count in dewatered fresh sludge.

sludge to the atmosphere. The lime furthermore appears to have a stabilizing effect on the sludge, so that dewatered fresh sludge, if disposed of on the ground, does not become a nuisance, regardless of exposure to the elements.

Bacteriologically, the disposal of dewatered fresh sludge shows much promise. One laboratory, on examination of 60 samples of dewatered fresh sewage sludge, failed to isolate any enteric pathogens (12). Bacteriological surveys conducted in the manufacturer's laboratories indicate that the chemicals used for conditioning the sludge, especially the lime, are markedly effective in reducing the numbers of coliforms in the sludge. With sludges containing confirmed MPN counts in the order of 10^9 organisms per dry gram, the conditioned and filtered cake consistently shows MPN counts ranging from zero to 10^3. An example of the effect of pH on the coliform count in dewatered sludge is shown in Figure 3. When the pH is above 9.0 there is a rapid decrease in coliform numbers. Since most sewage sludges are, in practice, dewatered in the pH range of 11.5 to 12.5, it can be expected that coliform counts in these dewatered sludges will be of a low magnitude.

Sludge Treatment

To the plant operator, the most significant factors affecting filterability of a sludge are those over which he can exercise control, in other words, those involved with preparation of the sludge for dewatering. After all, the nature of the sludge has been predestined by the characteristics of the sewage flow, and the equipment has been fixed by the design of the treatment plant; the operator's challenge is to get the best results he can with his sludge supply, and with the plant equipment at his disposal.

Sludge conditioning consists essentially of adding chemicals which coagulate and agglomerate the sludge solids. The specific reactions occurring between sludge components and conditioning chemicals have not been

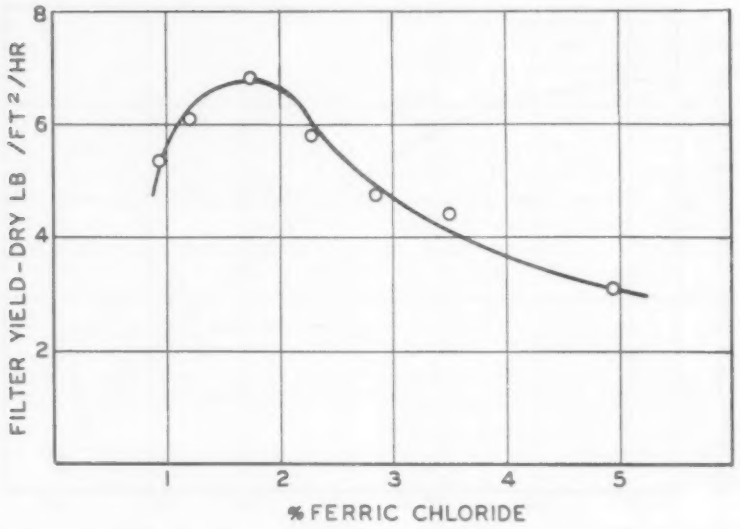

FIGURE 4.—Effect of ferric chloride dosage on filter yield in pilot plant vacuum filtration, using elutriated digested primary sludge. Sludge contained 7 to 9 per cent solids, and 6 to 10 per cent lime was added.

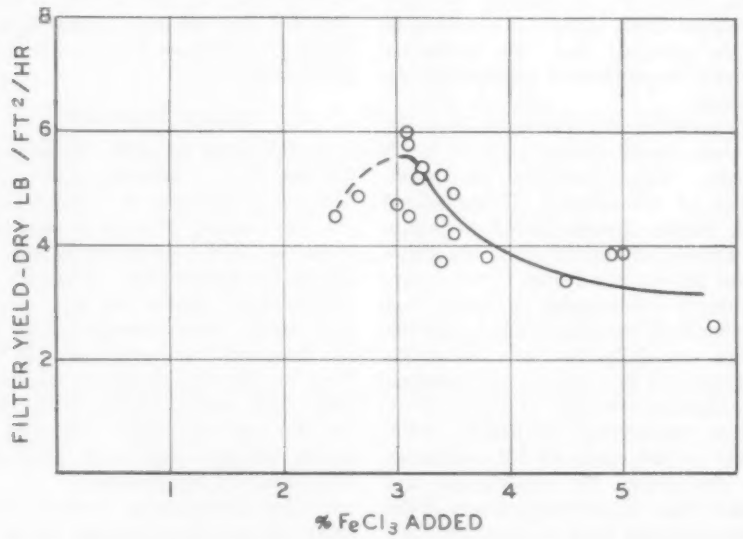

FIGURE 5.—Effect of ferric chloride dosage on filter yield, using digested primary and secondary sludge from a trickling filter plant. Sludge contained 7 to 10 per cent solids, and 11 to 19 per cent lime was added.

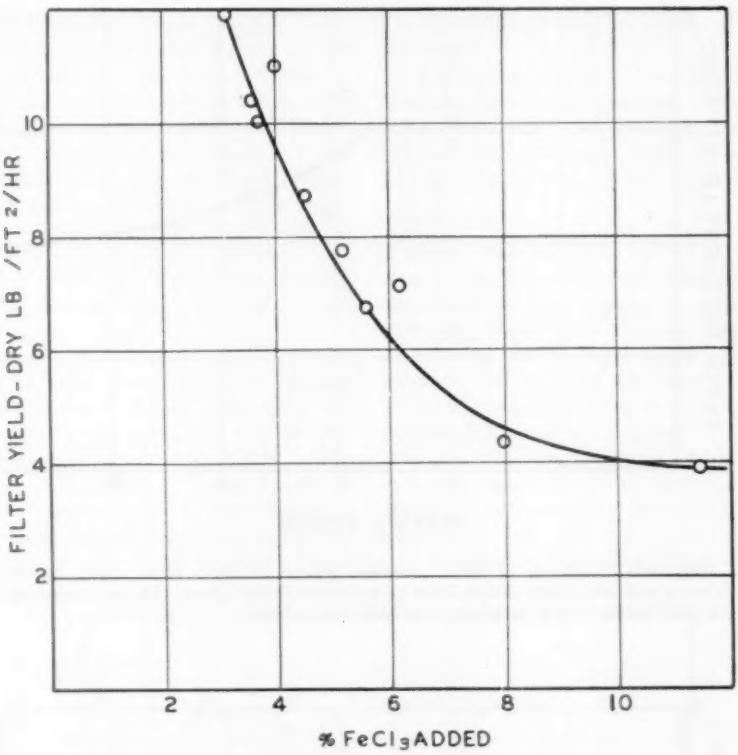

FIGURE 6.—Effect of ferric chloride dosage on filter yield, using elutriated digested primary and secondary sludge from a trickling filter plant. Sludge contained 8 to 9 per cent solids.

determined. Although many conditioning agents have been used with varying degrees of success, lime and ferric chloride are the most commonly used chemicals. There is promise at the present time that certain organic polyelectrolytes may be substituted for ferric chloride at lowered costs. However, this development is still in an experimental stage.

Coagulant Amounts

Genter (7) has provided a simple means for determining the approximate coagulant requirements for sludge filtration, taking into account the alkalinity of the liquid portion as well as the volatile content of the solid portion of the sludge. The elutriation process developed by Genter washes out the bulk of the soluble alkalinity and thereby minimizes the so-called "liquid demand" for ferric chloride and lime. As mentioned earlier, the removal of fines may be a factor here. In many instances an elutriated sludge can be successfully and economically dewatered with ferric chloride alone.

Very often, it is more economical to use both lime and ferric chloride with elutriated sludge, especially in view of the comparative costs of these two reagents.

A rather widely accepted practice consists of adding a somewhat higher chemical dosage than is required, as

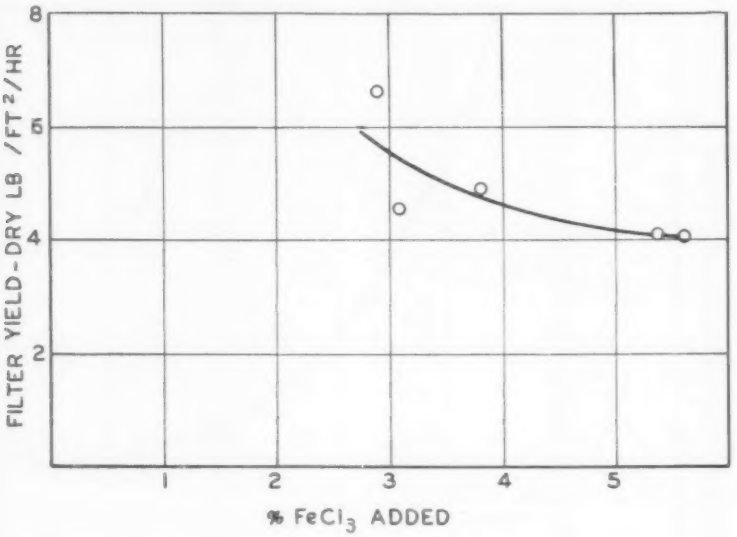

FIGURE 7.—Effect of ferric chloride dosage on filter yield, using digested primary and secondary sludge from an activated sludge plant. Sludge contained 5 per cent solids, and 8 to 12 per cent lime was added.

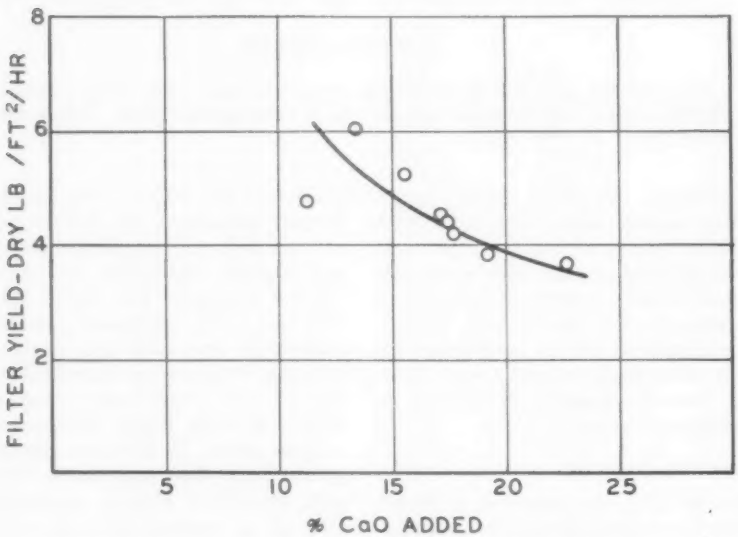

FIGURE 8.—Effect of lime dosage on filter yield, using digested primary and secondary sludge from a trickling filter plant. Sludge contained 8 to 10 per cent solids, and 3 to 4 per cent ferric chloride was added.

a safety factor. Such a practice, however, can result in lowered filter yields, just as underdosing does. Figure 4 shows the relation between ferric chloride dosage and filter yield under controlled pilot-plant conditions. It is seen that with the elutriated sludge under study optimum results were achieved with a dosage of between 1.5 and 1.85 per cent ferric chloride, and that the filter yield decreased rapidly as the dosage was increased beyond this range.

Figures 5, 6, and 7 show the relation between ferric chloride dosage and filter yield, drawn from data collected from the operating logs of several sewage treatment plants. The deleterious effect of overdosage is readily shown. It is interesting to note that, with one possible exception, the dosages employed at these plants have consistently been in excess of the optimum.

As shown in Figure 8, based on data from the operating reports at a sewage plant, filter rates can be depressed as a result of overdosage with lime, as well as with ferric chloride.

Overdosage

Since chemical cost is often the largest single item in the cost of filter operation, unnecessary overdosage, especially with ferric chloride, can be unduly expensive. The added cost is reflected not only by the cost of the chemical, but the added hours of operation that may be required. Thus, this practice can seriously upset the economic balance of a dewatering operation and should, therefore, be avoided.

A further contra-indication to over-

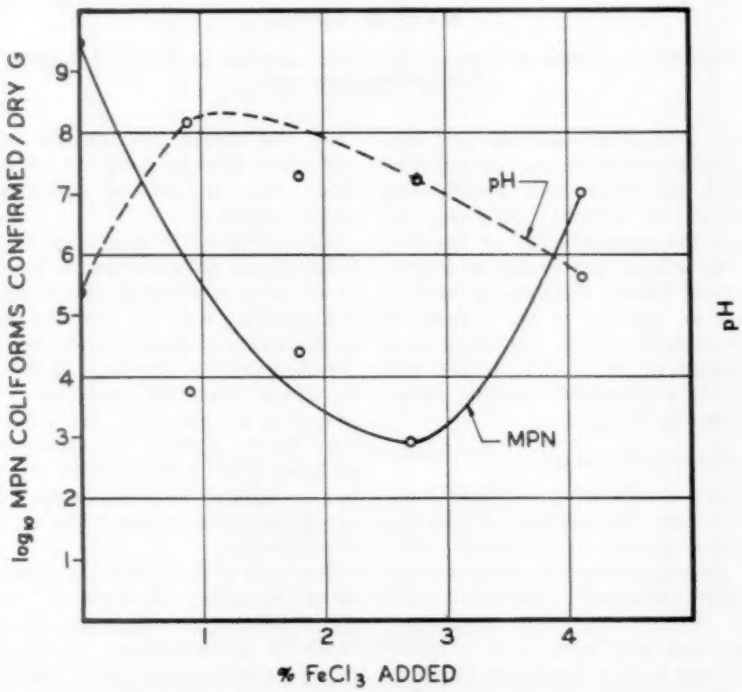

FIGURE 9.—Effect of ferric chloride dosage on coliform count in dewatered fresh sludge.

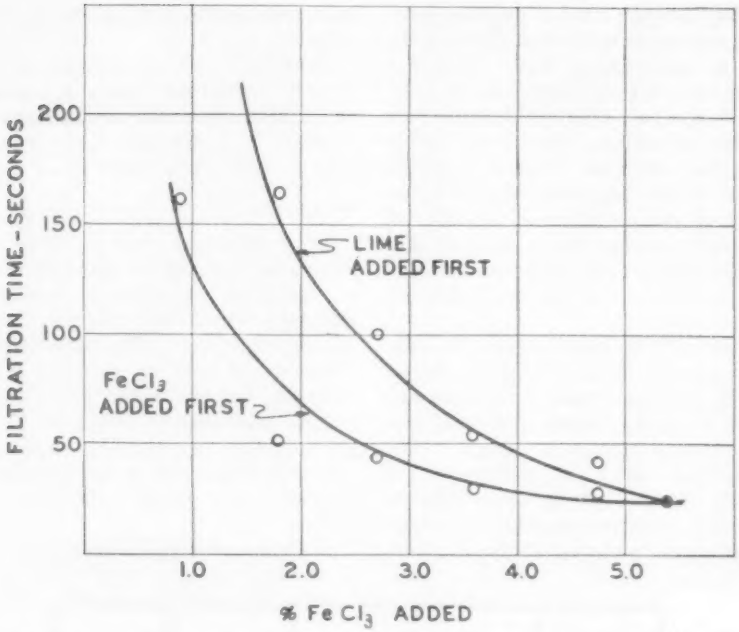

FIGURE 10.—Effect of sequence of chemical additions in sludge conditioning. Lime added—9 per cent.

dosage with ferric chloride is a bacteriological consideration. As has been pointed out, while both conditioning chemicals are effective colicides, the lime is the more effective of the two, and the pH of the sludge is a most important factor. With any given lime dosage an increase in the amount of ferric chloride added will result in a depression of pH, which in turn will result in a decreased colicidal effect, as shown in Figure 9.

Conditioning Technique

Proper conditioning requires more than merely the addition of the appropriate amount of chemicals. Certain techniques have been developed through operating experience, and have become accepted procedure. Often what may seem to be a minor detail may have a significant effect on the efficiency of the conditioning. For instance, the sequence in which the lime and ferric chloride are added can often have a profound effect on filter rate, as well as on chemical requirements.

From Figure 10 it is seen that, if a 100-second filtration time is accepted as an index of adequate filtration with the Buchner test, 1.5 per cent $FeCl_3$ is the indicated dosage if the iron salt is added prior to the lime; if the lime is added first, the required $FeCl_3$ dosage is 2.5 per cent. At a 5.5 per cent $FeCl_3$ dosage, the sequence of addition is not a factor with this particular digested primary sludge. Figure 11 shows a similar effect on lime requirements.

The type of lime used has a bearing on the efficiency of filtration. Many plants use a high magnesium lime because of its low price. It has been found, however, that a given filter rate is produced with a given CaO addition, regardless of whether the lime is

high calcium or dolomitic. Tests have shown that magnesium hydroxide is completely ineffective as an aid to filtration. It has also been found that on a CaO basis waste acetylene sludge, which consists primarily of $Ca(OH)_2$, is just as effective as hydrated lime.

Contact Time

The time of contact between the sludge and the conditioning chemicals has frequently been thought of as a factor affecting filtration. Evaluation has been made of the effect of deten-

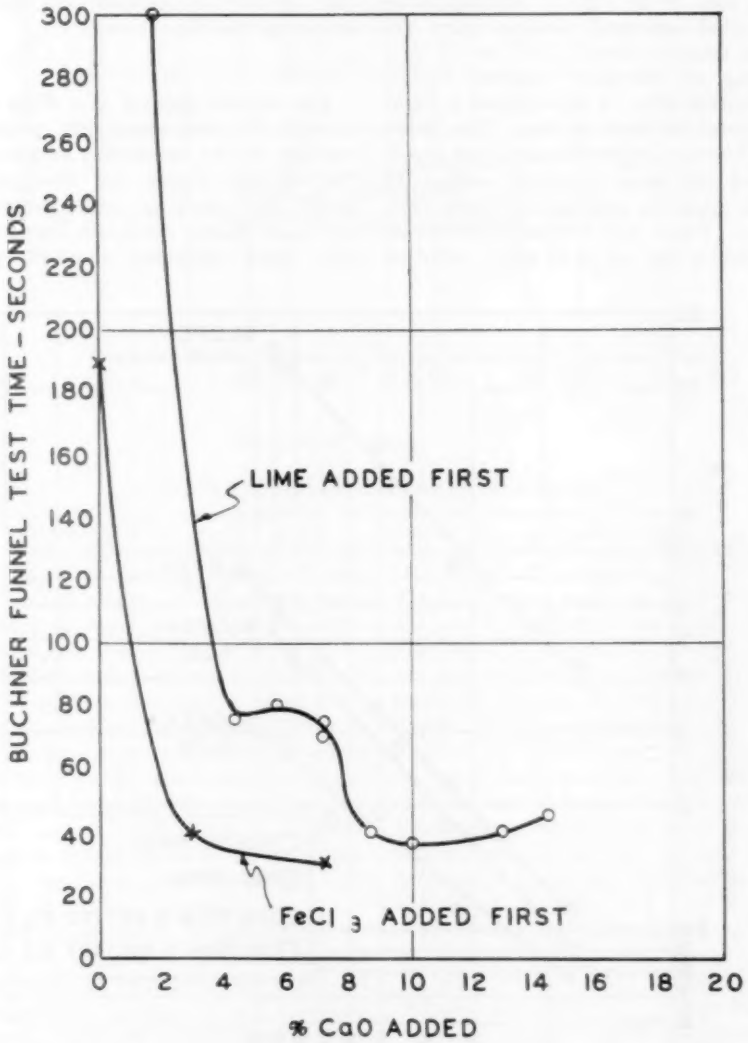

FIGURE 11.—Effect of lime dosage and sequence of chemical additions in conditioning of fresh primary and secondary sludge from an activated sludge plant. Ferric chloride used—2.1 per cent.

tion time using various sludges conditioned with ferric chloride and ferric chloride plus lime. While the relation of detention time to filtration rate varied among the sludges, in general it can be said that detention time up to 30 min after the addition of lime did not have a serious effect one way or the other. Actually, some digested activated sludges gave the best filtration rate after 8 to 16 min. Using an elutriated digested sludge, detention after 16 min showed a slight decrease in filtration rate. The greatest decrease in filtration rate was noted, using the same elutriated sludge, 12 min after the addition of ferric chloride. There was a steady decrease in filtration rate up to 30 min. After 30 min the filtration rate was about 80 per cent of that after 2 min. Apparently the amount and degree of mixing have a more significant effect on efficacy of the operation than does the contact time as such. Some sludges must be filtered immediately after the chemicals have been thoroughly mixed, and any further agitation will tend to break up the floc.

Vacuum

The vacuum applied in a filter represents the most significant physical variable in the treatment, or processing, of the sludge for dewatering. Halff (6), working with elutriated activated sludge, concludes that filtration rates remained constant with

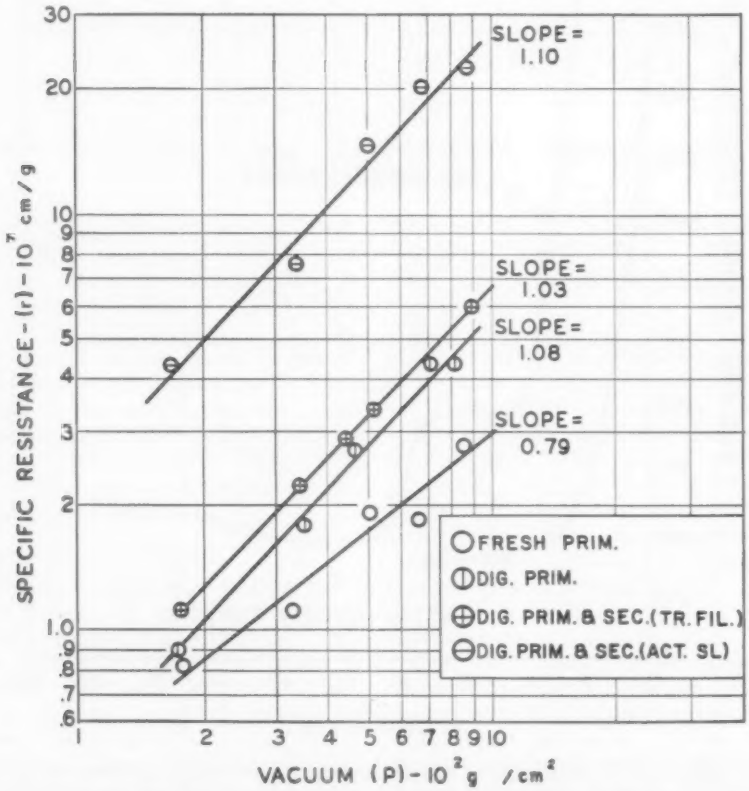

FIGURE 12.—Compressibility of conditioned sewage sludges.

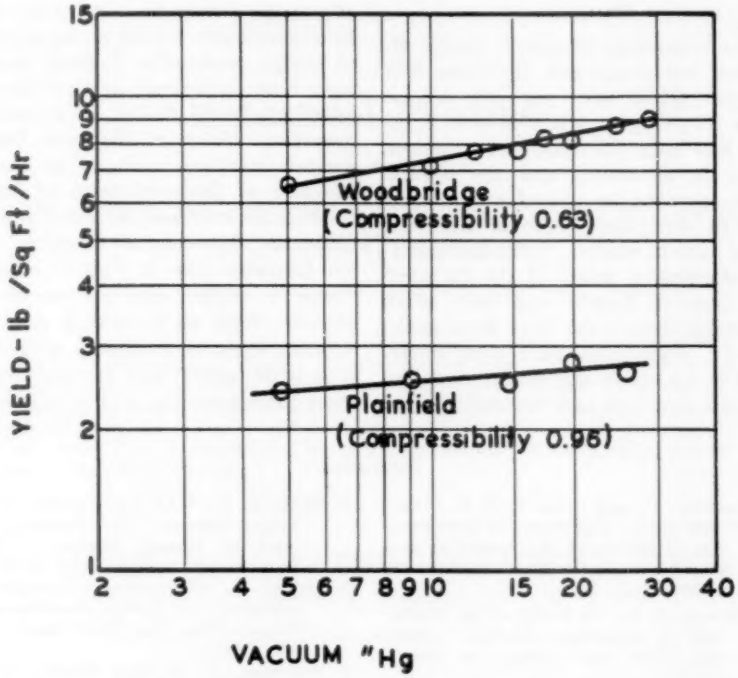

FIGURE 13.—Effect of vacuum on filtration rate.

vacua of 7.5 psi (approximately 15 in. of Hg) and greater. Jones, in the work cited above (3), states that most sewage sludges treated with ferric chloride have a compressibility of at least 0.85 and goes on to show that with sludges displaying compressibilities approaching unity, variation of the vacuum applied has little effect on the filter yield. According to Schepman and Cornell (8) cake moistures with various cycle times at a 15-in. vacuum corresponded to the cake moistures produced with the same cycle times at a 20-in. vacuum.

Determination of compressibility coefficients, using both specific resistance and leaf test measurements, on several conditioned sewage sludges confirms Jones' statement concerning the compressibility values of such sludges. With the exception of one sample which contained large quantities of grit, the coefficients as determined all fell within the range of 0.8 to 1.1. Typical results are shown in Figure 12. In Figure 13 it is shown that filter rates, as determined by leaf tests, are not significantly affected by increase in vacuum. With the Woodbridge sludge (containing grit) an increase in vacuum from 5 in. to 29 in. of Hg resulted in less than a 50 per cent increase in yield. With the Plainfield sludge, which is a more typical sludge, an increase in vacuum from 5 in. to 28 in. of Hg produced no significant increase in yield.

It would seem from the above that vacuums in excess of 12 in. or 15 in. of Hg are not required in dewatering conditioned sewage sludge; in fact, higher vacuums may be contra-indicated, at least from the standpoint of increased power requirements resulting in higher operating costs.

Summary

The technology of sewage sludge filtration has progressed since the first vacuum filters were put into service some 32 yr ago. Much of this progress has been the result of advances made in operation, and the sewage plant operator has played a significant role in developing vacuum filtration to its current status. From an operating standpoint, many of the chemical and physical factors and their effect on sludge dewatering have been established. Techniques have been developed to the extent that sludge dewatering is a practical and economical part of sewage treatment. Problems that have previously attended the disposal of sludge, especially of fresh sludge, have been minimized, so that the disposal of fresh sludge is a feasible operation. Some of the more fundamental questions, such as an understanding of the mechanism of conditioning, the reactions involved, and the difference between a filterable and non-filterable (or a "good" and a "poor") sludge, are yet to be explored. With an increasing need for vacuum filtration in sewage treatment it is to be hoped that the answers to these basic questions will soon emerge.

References

1. Coackley, P., and Jones, B. R. S., "Vacuum Sludge Filtration. I. Interpretation of Results by the Concept of Specific Resistance." THIS JOURNAL, **28**, 8, 963 (Aug. 1956).
2. Carman, P. C., "A Study of the Mechanism of Filtration. Part I." *Jour. Soc. Chem. Ind.* (Brit.), **52**, 280 T (1933).
3. Jones, B. R. S., "Vacuum Sludge Filtration. II. Prediction of Filter Performance." THIS JOURNAL, **28**, 9, 1103 (Sept. 1956).
4. Rudolfs, W., and Gehm, H. W., "Colloids in Sewage and Sewage Treatment. I. Occurrence and Role. A Critical Review." *Sewage Works Jour.*, **11**, 5, 727 (Sept. 1939).
5. Garber, W. F., "Plant-Scale Studies of Thermophilic Digestion at Los Angeles." THIS JOURNAL, **26**, 10, 1202 (Oct. 1954).
6. Halff, A. H., "An Investigation of the Rotary Vacuum Filter Cycle as Applied to Sewage Sludges." THIS JOURNAL, **24**, 8, 962 (Aug. 1952).
7. Genter, A., "Computing Coagulant Requirements in Sludge Conditioning." *Trans. Amer. Soc. Civil Engrs.*, **111**, 637 (1946).
8. Schepman, B. A., and Cornell, C. F., "Fundamental Operating Variables in Sewage Sludge Filtration." THIS JOURNAL, **28**, 12, 1443 (Dec. 1956).
9. Torpey, W. N., and Lang, M., "Elutriation as a Substitute for Secondary Digestion." THIS JOURNAL, **24**, 7, 813 (July 1952).
10. Trubnick, E. H., "Simplified Sludge Handling at Lower Cost." *Pub. Works*, **87**, 116 (1956).
11. Minneapolis-St. Paul Sanitary District, Twenty-Third Report (1955).
12. Sommers, L. C., Private Communication, Feb. 7, 1957.

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Industrial Wastes

OPERATING PROBLEMS OF INDUSTRIAL WASTES TREATMENT PLANTS

The following series of six papers comprised an operation forum dealing with industrial wastes treatment plants. These experiences were offered as a part of the Spring Meeting of the New York Sewage and Industrial Wastes Association at Liberty, N. Y., May 26–27, 1958. L. L. Hedgepeth,* Technical Consultant, American Cyanamid Company, was scheduled as moderator of the panel. In his enforced absence, K. S. Watson, Consultant, Water Management and Waste Control, General Electric Company, presided.

I. PLATING, HEAT TREATING, AND PAINTING WASTES

By J. M. Whalen

Plant Operator, International Business Machines Corporation, Kingston, N. Y.

The Kingston plant of International Business Machines is located three miles north of Kingston, New York, and approximately 600 yd east of the Esopus Creek, the receiving stream for the treatment plant effluent. At this location, the Esopus Creek is classified as a "B" stream by the New York State Water Pollution Board. The stream provides a minimum of 25:1 dilution during its low flows.

The principal uses of this stream below the treatment plant effluent are: swimming, boating, fishing for warm-water game fish and pan fish, and agriculture. It is also used as a source of water supply for some summer camps.

The sewage and industrial waste treatment plant is located approximately one half the distance between the creek and the main plant and at an elevation to allow gravity flow to the treatment plant.

History of Operations

The industrial waste is received from automatic platers, still plating lines and barrel lines, painting departments, and heat treating departments.

Each type of waste is collected and handled in a separate line. This provision has made for easier operation and has avoided accidental mixing of any two wastes.

The segregated waste lines entering the treatment plant contain the following:

1. Chrome waste, dilute rinse.
2. Chrome waste, concentrated chrome dumps of chromic acid copper stripping solutions.
3. Cyanide waste, dilute rinse.
4. Acid-alkaline or general rinse.

Waste oils are piped to an underground storage tank at the manufacturing plant for later removal.

In addition, concentrated cyanide, nickel strips, and solidified cyanide

* Deceased September 3, 1958.

heat treatment waste are trucked to the treatment plant.

The industrial waste treatment plant was originally designed as a batch treatment plant. During this period of batch operation, treatment proceeded as follows:

1. The cyanide waste was treated in two 7,500-gal tanks complete with mixing equipment, using the common akaline chlorination process at 10.5 pH and 7 to 8 times the cyanide content of chlorine.
2. Hydrated lime was used for pH control and chlorine gas for oxidation.
3. Chrome waste was treated in two 7,500-gal tanks complete with mixing equipment. Concentrated sulfuric acid was added to reduce the pH to 2.5, and sodium metabisulfite was used for reduction of hexavalent chromium, with hydrated lime being added for acid neutralization and chromium hydroxide precipitation.
4. Calculated weights or volumes of chemicals were added manually.
5. General rinse waste was batch treated in two 26,000-gal tanks.
6. Sulfuric acid or hydrated lime was used for pH control, the only treatment required.
7. The wastes, after treatment, were pumped to a 32,000-gal rectangular settling tank equipped with sludge collecting equipment. Baffles and rectangular weirs on the effluent end of the tank prevented floating material from being discharged to the effluent. Final effluent pH was near 8.0. Hexavalent chromium and cyanide were absent.
8. Settled, collected solids were pumped to a storage tank before being trucked to a final disposal site. As production increased, the batch treatment plant was operating at maximum capacity and an additional load was expected.

In order to provide complete and uninterrupted waste treatment and, in turn, uninterrupted manufacturing, it was decided to construct two 40,000-gal equalizing tanks, complete with pumps and connecting piping to the existing batch treatment tanks. One tank was designed for chrome, and one for cyanide waste. These tanks were originally sized to hold the volume of waste from 8 hr of production in order to assure continuous plating production.

In the next sequence of events the manufacturing facilities were expanded and the industrial waste plant was enlarged to accommodate the increased flows. By utilizing the existing holding tanks and batch treatment tanks, the system was changed to a continuous treatment system.

Automatic pH recorders and controllers were added to the chrome, cyanide, and final settling tanks. A manually controlled sulfur dioxide feeder replaced the metabisulfite in chrome treatment. The 32,000-gal settling tank was replaced with a 250,000-gal circular clarifier, complete with mixing equipment, chemical feed and sample lines, sludge collecting equipment, and automatic sludge valves which discharged to a 325,000-gal capacity sludge lagoon. Overflow weirs were installed in each of the six original batch treatment tanks, which connected to a 12-in. line to the clarifier.

As the expansion of the manufacturing and waste treatment facilities was completed, both were in full operation on a 24-hr basis.

A year later manufacturing was reduced to two 8-hr shifts. The waste treatment plant followed this schedule.

Operational Description

Cyanide Treatment

The cyanide waste is the result of the operation of two automatic cadmium platers, copper and cadmium still lines, and copper and cadmium barrel lines. The waste flows through a 6-in. tile line to a 40,000-gal holding-equalizing tank at the chemical feed building but, if desirable in operation, the holding tank may be bypassed and the waste brought directly to the treatment tanks.

The tank level is transmitted to depth gages in the control laboratory. Two cyanide pumps of 100-gpm capacity are provided to transfer the waste to the treatment tanks at the control building.

The pumped cyanide waste is maintained at a predetermined pH by the addition of hydrated lime. This is accomplished automatically with a pH recorder and controller, actuating a hydrated lime feeder. The waste is metered, recorded, and the rate of flow controlled automatically with a rate setter.

Utilizing the two original 7,500-gal batch treatment tanks, the waste is pumped to one tank and mixed. A 10.5 pH is maintained and chlorine gas is fed in excess to oxidize the cyanide to cyanates. The waste flows by gravity to the second tank where the pH is allowed to drop to 8.5. Chlorine residual is maintained for oxidation. The degree of treatment is recorded on a redox recorder in the range of 750 mv.

The cyanide waste will range in strength from 10 to 25 ppm. The present total daily flow ranges from 40,000 to 65,000 gal. In addition to the regular cyanide rinse, some concentrated cyanide nickel strip and a few 250-lb drums of cyanide heat treatment waste are trucked monthly for batch treatment.

The cyanide chlorinator has a 1,000-lb per day capacity. A manually controlled lime slurry tank is provided in the control building for pH control during batch treatment of concentrated cyanide. After treatment, the waste overflows a rectangular weir, a sample is piped to the redox recorder, and the waste flows through the common industrial line to the clarifier.

Samples from both tanks are pumped to the laboratory and checked for pH and chlorine residual. The sample pump discharges to the treatment tanks.

Cyanide strength of the raw waste is determined by titration with silver nitrate using rhodaine (Dimethylaminobenzalrhodaine) as the indicator. OTA and starch iodide methods are used for chlorine residuals. The holding tank is left nearly empty at the end of each working day.

Chrome Treatment

Chrome waste is received from the printed card department and plating departments. Chromic acid is a waste from copper etching and there are other chrome rinses in the plating departments.

This waste flows through a 6-in. tile line to the underground 40,000-gal holding-equalizing tank located at the chemical feed building. This holding tank may also be bypassed and the waste brought directly to the treatment tanks.

Two pumps are provided to transfer the waste to the treatment tanks. Capacities are 100 and 200 gpm, respectively.

The chromium waste has a solution of sulfur dioxide added before being discharged into the 7,500-gal treatment tank located at the control building. During treatment, a continuous sample is piped to the pH cell of an automatic pH recorder controller which actuates a sulfuric acid feed pump. A pH of 2.5 to 3.0 is maintained in the treatment tank. The waste is introduced at the bottom of the tank, flows upward with mixing, and passes over a rectangular weir which is connected to the common industrial line to the clarifier. Usual flow rates provide 40 to 50 min of contact with SO_2.

During treatment, a continuous sample is pumped to the control laboratory for visual check for hexavalent chromium and analysis, if necessary. The raw waste ranges in strength from 10 to 25 ppm chromium and the flows vary from 80,000 to 120,000 gpd. It usually requires 5 to 7 ppm SO_2 to reduce 1 ppm Cr at a pH of 2.5.

In addition to the dilute rinses there are dumps of concentrated chromic acid, copper stripping solutions which

are batch-treated with liquid SO_2 from 1-ton cylinders. As an example, a 250-gal etching solution requires approximately 650 lb of SO_2 at a pH of 2.0, or approximately 2.0 ppm SO_2 to 1 ppm chromium.

From this part of the treatment, the waste flows, either by gravity or is pumped, to the common line to the clarifier where final pH adjustment is made to 8.5 in preparation for chromium hydroxide precipitation.

General Rinse

The general rinse includes all the industrial wastewater used, except the chrome and cyanide rinses.

This waste flows directly to one of two 26,000-gal (complete with mixer) tanks for equalization and then to the common line leading to the clarifier. The daily volume usually is in excess of 200,000 gal. Waste samples are pumped to the laboratory for analysis. One tank operates continuously and the other is kept for unusual dumps of either acid or caustic. An attempt is made to use one against the other for neutralization. One tank is left empty at the end of the day in preparation for subsequent waste flow. The pH of the general rinse is adjusted with other waste at the clarifier.

Final Treatment

All treated wastes flow to the clarifier in a common 12-in. pipe and enter at bottom center. Present detention is approximately four hours during peak flows.

The clarifier is a cylindrical concrete tank, 50 ft in diameter and 13 ft deep, with a capacity of 250,000 gal. Mixing, coagulation, recirculation, settling, and sludge collection are accomplished in this unit.

A pH of near 8.0 is maintained at the clarifier by the addition of hydrated lime. The system of control is basically the same as previously stated for cyanide treatment except that an auxiliary pump is employed to take samples of the tank mixture.

From the clarifier peripheral weir the effluent flows through a weir chamber and over a 90° V-notch weir for flow recording, and then flows out through a 12-in. pipe to the Esopus Creek.

Sludge is intermittently discharged from two sludge hoppers at the bottom of the clarifier by two solenoid-operated diaphragm sludge valves. A motor-driven sludge collecting mechanism is employed to scrape settled material into the hoppers.

Effectiveness of Treatment

Composite samples of the final effluent are collected regularly for laboratory analysis. Typical results are as follows:

Determination	Concentration (ppm)
Alkalinity (methyl orange)	20–30
Suspended solids	15–30
Hexavalent chromium*	0
Cyanide†	0
pH‡	7.5–8.5
Dissolved oxygen	5–7

* Measured photometrically using 1,5-Diphenylcarbazide indicator.

† Using Serfass reflux method and pyridine-pyrazolone color test.

‡ Grab samples.

Operational Problems

The treatment of chromic acid copper stripping solutions has been a particularly difficult problem. When the treatment plant was operated on a batch basis these solutions were treated with sodium metabisulfite, which was added manually from 100-lb bags.

For treatment, this 250-gal solution was diluted to 5,000 gal using normal chromium rinse. The pH at the start of treatment was 1.8 to 2.0. Depending on the strength of the solution, 6 to 1,200 lb of $Na_2S_2O_5$ was used, and sometimes 100 to 200 lb of sulfuric acid was used to maintain a low pH.

Considerable discomfort was associated with the dust from the batch treatment operation. The fact that this job was outside added to the discomfort during inclement weather.

The first operational improvement

was to invert 150-lb SO_2 cylinders and actually pour the liquid through connecting piping to the chrome treatment tank. This was a great improvement since the treatment could be performed inside; no additional acid was required; and the chemical handling was reduced.

However, as the frequency of dumps increased, the chemical handling problem increased accordingly. The next step was to purchase SO_2 in 1-ton drums. This not only resulted in great savings on chemical cost but reduced chemical handling and provided ease of operation.

The industrial waste sludge build-up was much faster than anticipated because of increased production. In an effort to find an economical method of sludge disposal it was decided to pump industrial waste sludge from the sludge lagoon to the uncovered sewage sludge drying beds. It was found possible to pump 1,000 cu ft of wet sludge containing 8 to 10 per cent solids and in good drying weather to remove 300 cu ft of dried sludge in 4 to 5 drying days. The sludge was removed as soon as it was possible to handle it with forks.

During the batch operation period, the paint department began to experience foaming trouble with the spray booths. To improve the production problem it became necessary to dump the 1,200-gal tanks containing painting waste at least every other day. At this time, the industrial waste treatment plant was operating at near full capacity. Therefore, the paint dumps were volume considerations as well as the cause of settling problems in the treatment. However, satisfactory settling results were obtained when the paint dump was acidified to a pH of 2.5 to 3.0, followed by a pH rise to 8.5 to 9.0 effected by the addition of hydrated lime.

Later, the paint waste volume was reduced when it was found possible to lengthen the holding time of the wash water by the addition of an antifoam agent.

II. STEEL MANUFACTURING WASTES

By V. P. Traina

Sanitary Engineer, Republic Steel Corporation, Buffalo, N. Y.

Operating problems of an industrial waste treatment plant vary from industry to industry and also from plant to plant within the same industry. Industry as recognized today is a complex operation producing many diversified products. Its operation is governed by the demand that exists for a particular product. As the demand for one product diminishes, its production is curtailed and another product in demand will be produced. The same complex situation exists in the field of industrial waste treatment.

Production Factors

In the steel industry, the nature and character of the waste products may be determined by three factors: (a) raw material used, (b) final product, and (c) manufacturing process. Tremendous variations exist in these factors, and equally large variations exist from plant to plant within the same industry. One plant may produce its own coke; another may purchase it. One plant may use Mesabi ore from Minnesota and another Liberian ore, and a third a combination of these ores. The combinations of these factors are unlimited when it is considered that industry's primary aim is producing a product that is in demand at the cheapest cost.

The biggest and most important job for industry today in any waste control program is to find out what it is doing. For many years industry has been preoccupied with expansion. In keeping up with demanding produc-

tion schedules, expansion programs are quickly executed. As a consequence, the usual result has been that vital data and complete facilities for waste treatment were omitted because of a lack of appreciation of their importance. Now, for economic reasons as well as the necessity to yield to the pressure exerted by waste-abatement laws, industry has had to turn around and look at the by-product and waste resulting from the manufacturing process.

Waste Characteristics

In taking this look industry has learned that the methods and techniques developed by the municipal sewage treatment field are not always applicable. Many process operations are intermittent. Sampling must be integrated with operations; it cannot be an independent survey. Depending on each industrial plant, water discharges may or may not be segregated. Storm water, cooling water, process water, and sewage may be discharged from one sewer or from separate sewers. Some process water may be diluted by others. On the other hand, strong solutions may be discharged separately and analytical methods, already developed and used for low concentrations and few interfering agents, can give erroneous results.

If wastes from different processes are mixed, further complications are encountered. Measuring the wastes separately may not give any indication of the synergistic effect, if any, of the mixed wastes. Yet the mixed waste is the real discharge and it is the effect of this that must be controlled. These effects usually cannot be measured by concentration alone and considered as the "maximum allowable concentration" which is commonly used as a waste strength criterion.

Stream Use

The primary objective of both sewage treatment and industrial waste treatment is the protection of the receiving stream. However, with the development of the sewage treatment field, the objective of design became percentage treatment—BOD and solids reduction. A sewage treatment plant has either primary, intermediate, or complete treatment. Some present problems with algae bloom and tastes and odors may be traced to this shift in objective from stream protection to percentage treatment.

In the industrial waste treatment field it is important not to lose sight of the primary objective—stream utilization. Measuring of plant discharge alone does not measure effect. Analyses of innumerable organic compounds in industrial discharges provide no knowledge of degradation in the stream. Measurement of solids on a dry weight basis ignores the size of the particle—micron- or boulder-size. Phenol has been controlled because it supposedly causes tastes and odors. But actual odor samplings in the receiving stream have shown other organic discharges to be the cause of odor. Phosphates and nitrates have always been considered a measure of the stability of a receiving stream; yet they can cause algal blooms with taste and odor problems.

Batch operations as well as variations in the process operation itself are common in industry. These variations drastically affect the discharge to the receiving stream. The slugs produced vary in time interval, volume, and character. A 24-hr composite sample or even an 8-hr composite may not measure the true effect on the receiving stream. If treatment facilities are available, they must be able to handle these slugs, and the operator then becomes an important individual.

Operation and Management

Operating control of waste treatment plants is not only important at the treatment plant but also back at the process itself. A slight change in the

process or in its operation may be more advantageous than complicated and costly treatment. It may appear strange but treatment plants are not always needed to accomplish the desired objective. Education of the personnel operating the process may often solve the problem. Conservation of material has also provided many solutions.

Industrial waste control starts with management's appreciation of its importance. The program must necessarily be integrated into operation and planning. The personnel involved must know every phase of the production methods used in the plant. They should be posted on any change in the operating pattern of the production department and know how these changes will affect the receiving stream. They should be in a position to suggest and recommend to the production departments changes that will decrease the load of waste products or increase the efficiency of their treatment facilities.

With an appreciation that operating problems of industrial waste control programs necessarily extend into management, operations, engineering, material purchasing, accounting, public relations, regulatory agencies, and neighboring industries; there can be a recognition that industrial waste control is a challenge. To meet the challenge, each program must be tailor-made. It must be developed for each industry with maximum flexibility and imagination in order to coordinate many activities and reconcile a variety of opinions.

III. WASTE ACID NEUTRALIZATION

By T. J. Tully

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The General Electric Company Silicone Products Department plant at Waterford, N. Y. is a chemical processing plant engaged in the manufacture of a wide variety of silicone resins, fluids, and elastomers. Like other chemical plants the waste is large in volume and diverse in character.

Physically these wastes vary from gas, through liquid, to solid. Chemically, they range from strongly alkaline to strongly acid. Consequently, the waste disposal program is of necessity somewhat flexible in nature.

Solid material which is primarily spent silicon powder and silicone gel, is disposed of by burial in the ground. Gases are scrubbed to remove acids and silicone vapors and are vented to the atmosphere. Liquids are discharged to the Hudson River after treatment to remove the bulk of the silicones, acidity, and/or alkalinity that may be present. This paper is confined to the liquid waste treating facility.

Since most of the liquid wastes are acidic in nature the treatment is designed primarily to neutralize this acidity. The acid is mostly hydrochloric, plus some sulfuric. The treatment also serves to remove the silicone gel, which is present in relatively low concentrations in some of the wastes.

Evolution of the System

The acid-neutralizing operation in its present form has evolved from a quite different original concept of treatment. The initial facility, installed in 1946, was designed to collect acid wastes in an agitated tank, neutralize the acidity with caustic soda solution, and discharge the neutralized effluent in batches to the sewer. This method of treatment, while theoretically feasible, proved in operation to be costly and difficult to control and

was modified in 1953 into the present up-flow limestone bed type of facility.

The up-flow limestone bed method of neutralizing acid wastes was originally reported by Gehm (1) (2) in 1944. To determine its applicability to the type of acid wastes encountered at Waterford, a series of laboratory tests were conducted in 1952. These tests consisted of pouring acid solution through a 12-in. bed of limestone contained in a length of 2-in. glass pipe. Evaluation was made by varying the loadings.

Based on these laboratory data the initial limestone bed installation was designed. It consisted of a settling section, a mixing and dilution section, two limestone beds, an effluent collecting section, and a discharge sump. The limestone beds were approximately 3 ft deep, 55 sq ft in cross sectional area, and were designed to operate at a flow of 1.3 gpm per sq ft of bed area. A schematic flow diagram of the system is shown in Figure 1.

Vent gases containing HCl and silicone vapors from various parts of the plant were collected and scrubbed in a water eductor in the settling section of the pit. The HCl present in the gas was dissolved in the water and passed into the mixing section. The silicone vapors were condensed and floated on the top as a gel. The scrubbed gases escaped to the atmosphere.

Liquid acid wastes, also containing silicones, were introduced from pipe lines into the mixing section of the unit. Here they were diluted by weak acid effluent from the settling section and fresh water from an eductor. The eductor was employed to lift acid from a collecting sump below the limestone bed level.

The diluted acid was then fed via a wood grid and coarse coal distributing system upward through a 3-ft bed of limestone where neutralization took place. Limestone was added to the beds periodically from an open hopper by means of a manually controlled belt conveyor. The neutralized effluent ran into a collecting chamber, discharge sump, storm sewer, and finally into the Hudson River.

Operation emphasized the need for certain improvements as indicated by the following observations:

1. Neutralization efficiency was poor since the influent acid strength was variable and the limestone was not in uniform suspension in the liquid.
2. Silicone gel clogged the limestone beds and reduced neutralizing efficiency.
3. In cold weather the open top limestone feed hopper and conveyor col-

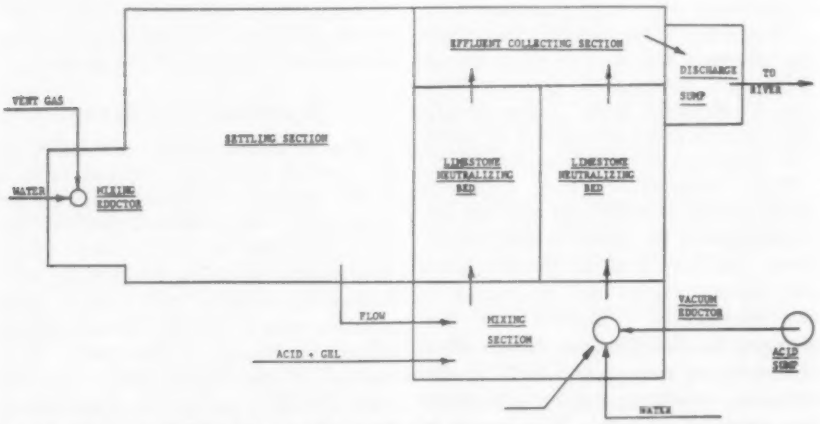

FIGURE 1.—Schematic plan view and flow diagram of first acid neutralization system.

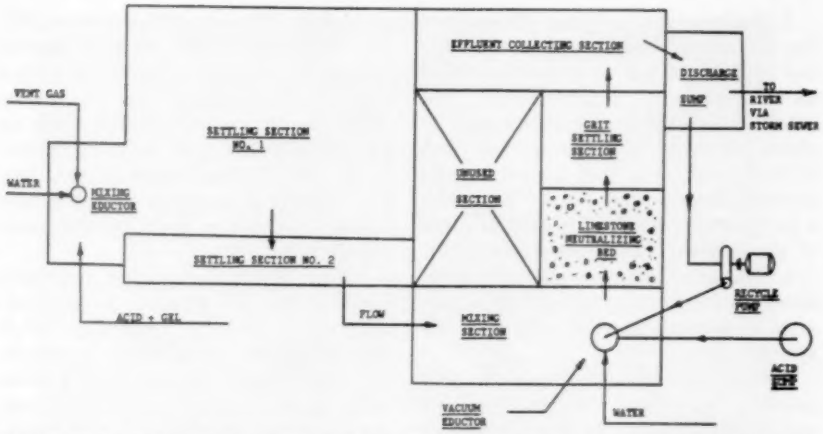

FIGURE 2.—Schematic plan view and flow diagram of existing acid neutralization system.

lected water which froze and interfered with smooth operation of the system.

4. Limestone distribution in the beds was uneven. This resulted in channeling of the effluent and consequent inefficient neutralization.

Present System

To correct these defects the system was modified in 1956 to accomplish the following objectives. The revised installation is shown schematically in Figures 2 and 3.

1. Provide more uniform and more dilute acid feed to the bed by increasing the holding capacity of the settling and mixing sections. This was done by increasing the wall heights.

2. Minimize silicone gel carryover into the limestone bed by introducing all silicone containing waste streams into the settling section, where gel can be removed.

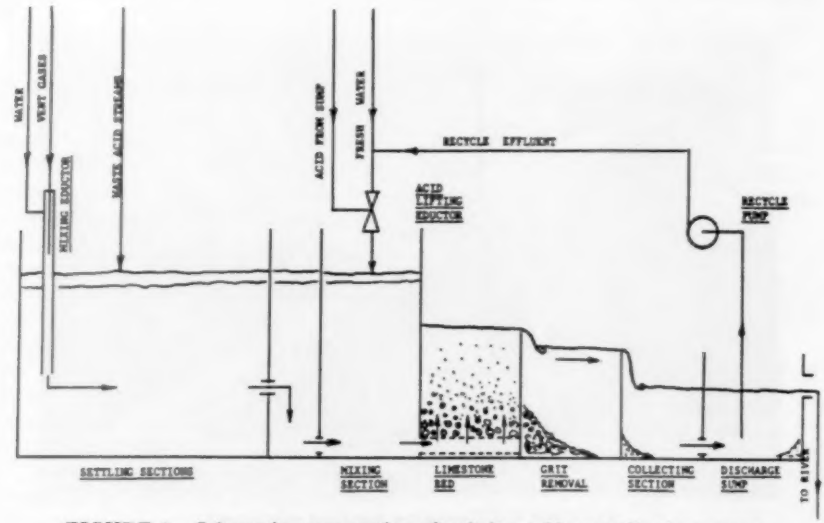

FIGURE 3.—Schematic cross section of existing acid neutralization system.

3. Improve neutralizing efficiency of the limestone bed by: (a) reducing bed area by 50 per cent and installing an effluent recycle pump to boost flow rate through the bed from 1.3 gpm to about 20 to 30 gpm per square foot of bed area, and (b) improving the influent distribution to the bed with a perforated pipe feed system in place of the original wood grid system.

4. Minimize freezing of the limestone feed system by providing a covered, elevated storage bin and conveyor system.

5. Minimize labor requirements and provide maximum neutralizing capacity by installing an automatic control to maintain an optimum level of limestone in the bed.

6. Improve control by providing a pH recorder to monitor the operation.

These modifications allowed the limestone bed to maintain better particle suspension, minimized channeling, and made the bed completely self cleaning. The current bed has operated 9 months without any noticeable accumulation of solids.

As further results of these modifications the system is able to operate satisfactorily at influent acid flow rates as high as 750 gpm of 1 per cent HCl. The average amount of acid passing through the system is normally only a fraction of this amount and the volume difference through the bed is made up by fresh water and recycle effluent. Figure 4 is a photograph of the limestone handling equipment and Figure 5 is a view looking down on the entire installation.

Labor requirements for operation average 2 to 3 man-hours per day, seven days per week. Operators check the operation several times per shift, each time stirring the bed with a metal rod to make certain that the limestone particles are suspended in the acid stream. They also check and initial the pH recorder chart and make necessary adjustments in the water and recycle effluent flow rates.

Periodically it is necessary to remove the gel that accumulates in the settling section. This is done by pumping, as a slurry, to a truck for hauling to a solids disposal area for burial.

Once or twice a year the grit settling and collecting sections are cleaned to remove the limestone which has been carried over from the neutralization

FIGURE 4.—Limestone handling equipment.

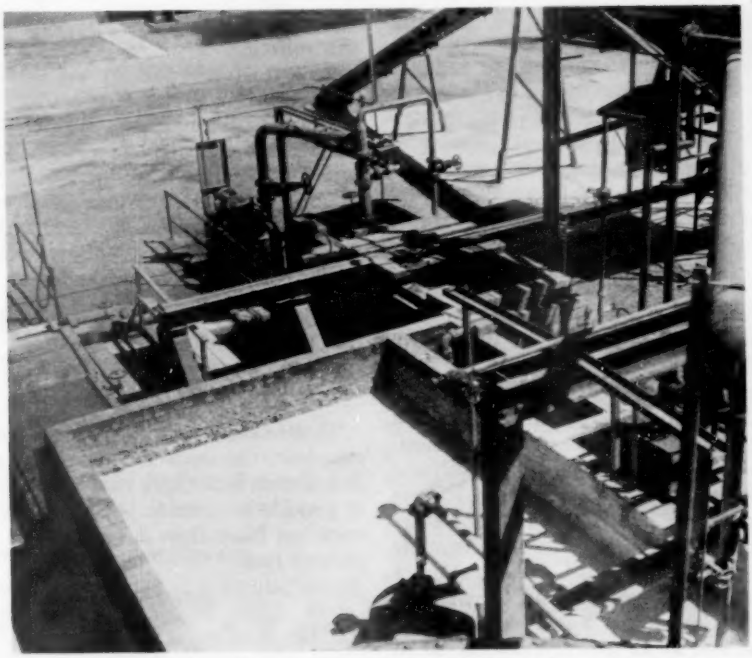

FIGURE 5.—View from above acid neutralization system.

section. Occasionally the limestone level controller fails to function properly and stone spills over into the settling section.

Costs

The neutralizing bed is composed of 94 per cent soluble, high-calcium limestone, ¼ in. or smaller in size. This stone is obtained locally and costs $4.00 per ton of which $1.00 represents transportation cost. It may be of interest to note that at the time the limestone bed type of operation was under consideration a total of 14 different samples of limestone were evaluated in the laboratory. The cost of the various limestones ranged from $3.65 to $16.00 per ton and solubilities varied from 66 to 96 per cent. The stone selected combined low cost and high solubility to provide satisfactory operation.

On the basis of material costs alone, limestone is by far the cheapest method of neutralizing waste acids of the type encountered at Waterford. A recent cost comparison is shown in Table I.

The index given in Table I represents the material cost of neutralizing a given quantity of acid with a particular neutralizing agent divided by the cost of neutralizing the same quantity of acid with limestone.

The total capital investment in the present treatment facility is about $35,000, of which $20,000 represents the initial cost and $15,000 the expenditure for later modifications.

On the basis of neutralizing one ton of 1 per cent hydrochloric acid the unit cost of operating the waste acid neu-

TABLE I.—Summary of Cost Comparison of Acid Neutralizing Agents

Neutralizing Agent	Delivered Cost ($/ton)	Index (Limestone = 1)
Limestone	4	1
Lime	20	2.3
Soda ash	40	9.0
Caustic soda	60	10.2

tralizing facility at Waterford at the present time is as follows:

Item	Cost
Direct labor	$.094
Limestone	.121
Depreciation	.105
Maintenance	.167
Power	.003
Total	$.490

Summary

To summarize, the General Electric Company silicone plant at Waterford, N. Y. is currently operating an "upflow limestone bed" type acid neutralizing unit. This unit receives a variety of influent waste streams containing both hydrochloric and sulfuric acids in varying concentrations. These streams are diluted with fresh water and recycle effluent from the limestone bed to an average acid-concentration of less than one per cent and then passed upward through a 3-ft expanded limestone bed at an average rate of 20 to 30 gpm per square foot of bed area. The effluent pH averages 4.0 to 6.0. Current cost of operating the neutralizing facility is about $0.49 per ton of one per cent hydrochloric acid neutralized.

This treatment facility has been developed over a period of years by making successive alterations to an original caustic soda neutralizing unit. Because of limitations imposed by an existing structure, the unit is not completely ideal in all respects. A later design based on 12 yr of experience would recommend these changes:

1. Provide a deeper limestone bed, possibly circular in cross section.
2. Provide a collection or equalization section with a larger capacity.

These changes would tend to minimize variation in feed composition and flow through the bed and hence make it possible to operate the facility with even less labor than is required at the present time.

References

1. Gehm, H. W., "Neutralization of Acid Waste Waters with an Up-Flow Expanded Limestone Bed." *Sewage Works Jour.*, **16**, 1, 104 (Jan. 1944).
2. Gehm, H. W., "Up-Flow Neutralization of Acid Wastes." *Chemical and Metallurgical Engineering* (Oct. 1944).

IV. OIL REFINING WASTES

By F. E. Ray

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Oil refineries use large quantities of water. This may amount to 30 gal of water for each gallon of crude oil processed. For a medium-sized refinery this quantity can be 100,000 gpm. The water is used for cooling and condensing; product and equipment washing; and steam production for power generation, heating, purging, and processing.

Oily wastes can enter sewers from many points because of condenser leakage, pump gland leakage, water withdrawals from product accumulators, sampling connections, spills, line breakage, and similar conditions. Substantial volumes of oil may be released to the sewers during shutdowns of operating units, equipment cleaning, and start-ups. Depressuring and purging vessels in cyclic operation may discharge heavy oil to the sewers. Water washing products after chemical treatment results in loss of oil to sewers. Other sources include withdrawal of salt water from crude oil desalters, withdrawal of water from the bottom of crude and product tanks, and the drainage of storm water from processing and storage areas.

Chemical wastes also enter the sewers from the same sources. These wastes may be in the form of solutions or suspensions and are classified according to their effect on the characteristics of the water. Such characteristics include solids content, acidity, alkalinity, pH, oxygen demand, toxicity, taste and odor, color, and turbidity.

Segregation Procedures

It is now general practice to install separate drainage and sewer systems. This prevents pollution of large volumes of clean water by small volumes of contaminated water. An example of a suitable sewer system, as recommended by the American Petroleum Institute (1), is described below.

Storm-Water Sewer System

The contaminated storm-water sewer system collects surface water from processing and tankage areas, which normally contain oil, and conveys it to the storm-water separator. Peak separator loads may be reduced by controlling the runoff of diked areas or by providing surge volume by the use of a pond.

Cooling-Water Sewer System

Once-through cooling water from condensers and coolers—when the oil being processed is a condensable product which will not vaporize rapidly on exposure to the atmosphere—is sewered to the contaminated cooling-water separator. Barometric cooling water subject to separable oil contamination, but not containing emulsified oil, can be included in this system.

Oil-free Bypass Sewer

The oil-free sewer collects wastewaters not having contact with oil, and bypasses them around the separators to the refinery effluent water sewer. This system includes uncontaminated storm water, cooling water from turbo-condensers and air conditioning equipment, roof drainage from large buildings, boiler blowdown, ion-exchange regeneration water from water treatment, and decanted filter backwash and coagulation sludge from water treatment. Once-through cooling water from condensers and coolers normally handling gaseous products can be included in the oil-free sewer system.

Sanitary Sewer System

Untreated sanitary sewage is excluded from wastewater separators in order to prevent any possibility of interference with sedimentation and separator effectiveness. The sanitary sewer system collects raw sanitary sewage only and conveys it to municipal sewers or to treatment facilities within the refinery. The effluent line conveying the discharge from the refinery sanitary sewage treatment facilities to the separator effluents is considered a part of the sanitary sewer system.

Process-Water Sewer System

The process-water sewer system collects all wastewaters which come in direct and continuous contact with oil and others which are subject to emulsified oil contamination. These wastes will generally require treatment in addition to gravity separation. After gravity separation any emulsified oil remaining in the effluent may be removed in a chemical coagulation treatment unit, or by other secondary treatment. These waters include drawoffs from accumulators and knockout drums, condensate from steam-stripping operations, desalting wastewater, pump-gland cooling water, barometric condenser waters containing emulsions, cooling tower blowdown, and any other sources known to contain emulsified oil. The advantage of segregating these wastes is to prevent formation of emulsions in the main sewer systems. Proper segregation of low-solids process water from high-solids process water will permit reuse of the former as

cooling-tower make-up. This is reported to lower the oxygen demand of such wastewaters and to reduce the total volume of wastewater leaving the plant.

Ballast-Water Systems

These systems consist of ballast-water settling tanks equipped with oil-skimming devices.

Special Systems

These systems include the lines and treatment facilities for handling liquid wastes such as spent acid, spent caustic, and sulfur-bearing waters having an objectionable odor.

Separators

The primary oil and water separation is performed in gravity-type separators. Research has provided design methods for inlet systems, oil skimming, and sludge removal.

However, gravity separators will not remove all emulsified oil. Emulsions are generally broken by application of heat or chemicals before they are discharged to the drainage system. Flocculation by the addition of chemicals such as aluminum or iron compounds or flotation with minute air bubbles is often employed after the gravity separator to further reduce oil content.

Waste Treatment Procedures

While a variety of chemical wastes are encountered in refinery operations, acids, alkalies, sulfides, and phenols are the most common ones requiring treatment. Acid and alkaline waters are usually neutralized by mixing with each other or by adding spent acid or caustic.

Before wastewater can be biologically treated for phenol removal, sulfides must be reduced to 10 ppm or less. As a result, wastewaters containing sulfides are neutralized and stripped of H_2S with steam or flue gas.

Aerobic oxidation is the biological treatment for phenols generally used in a refinery. Several of the commercial aerobic biological processes have been adapted to this treatment. Each process requires the maintenance of conditions suitable for the growth and activity of aerobic organisms.

Phenolic wastes may be discharged to cooling towers. Phenols and other materials exerting a BOD are oxidized by bacteria when proper environmental conditions exist in a cooling tower. This procedure is used if sliming of process equipment is not a limiting factor. Back-flushing of exchangers and condensers is practiced to minimize fouling with slime.

Other treatment processes used are trickling filter, activated-sludge, and oxidation pond. Dual combinations of these processes are sometimes used to minimize the deleterious effect of fluctuations in the waste feed.

The major benefits to be gained from the biological treatment of refinery-wastewaters include reduction in BOD and oil content; and improvement in taste, odor, and appearance. Reductions in BOD of approximately 95 per cent have been obtained. The effluent is essentially free of oil. Reductions of 40 to 85 per cent in the threshold odor number have been obtained. Each of the three processes is capable of reducing phenol content by 90 to 99+ per cent. Turbidity and, in some instances, color are substantially improved by each of the three treatments.

Preventive Methods

Preventive methods other than treatment are in common use in most refineries for reducing the amounts of polluting wastes. They include water conservation, process modification, reduction in product and chemical losses, and recovery and reuse of waste streams. Examples include the installation of cooling towers or air-cooled exchangers to minimize water demand, multiple use in series of various water

streams, regeneration of spent caustic and acid wastes, and reuse of partially-spent caustic and acid streams from one process in another process where lower strength is acceptable.

Summary

Refinery waste disposal is a different problem for each refinery. Techniques are available for lowering the quantity of waste streams and concentration of pollutants to be handled and for treating these various streams. However, each refinery has to select the techniques most suitable for its particular needs. Segregation of streams in accordance with the type of pollutants contained is generally desirable and is usually practiced when building a modern refinery. In older refineries with a common sewer, the cost of installing a new segregated sewer system is often prohibitive and the entire effluent must be treated—also an expensive procedure.

Reference

1. "Manual on Disposal of Refinery Wastes." Vol. I, American Petroleum Institute, New York, N. Y. 5th Ed. (1953).

V. DAIRY WASTES

By Arthur H. Klein

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In an earlier review, Trebler and Harding (1) discussed waste problems and solutions arising from the processing of some 120 billion pounds of milk annually in over 30,000 plants. His main point was that it will always be cheaper to keep milk out of the sewer than to put it in and then remove it with expensive waste treatment methods. However, it always becomes necessary to discharge a wash or rinse solution containing milk. Since this discussion is primarily for operators concerned with the treatment of those wastes, in-plant control and reduction of milk losses will not be stressed, despite the great necessity for such a program in dealing with milk wastes. Furthermore, it should not be necessary to sell that idea to the dairy management, since every drop of milk in the sewer represents a financial loss.

Review

Concerning treatment, Trebler added that, contrary to popular belief, dairy wastes are about the easiest ones to treat by biological methods because milk and milk products are nature's most nearly perfect foods for microorganisms as well as for man. The solids consist of fats, proteins, and carbohydrates in various proportions, depending on the type of process. The wastes usually exhibit relatively high BOD, little of which is removed by sedimentation. By making allowance for these factors, milk wastes can be treated successfully by existing biological methods in any municipal sewage treatment plant that has sufficient secondary treatment capacity.

Pretreatment to remove sand and fat is desirable. Where only primary treatment is available, pre-aeration can be used to oxidize lactose which is soluble. With secondary treatment, pre-aeration is unnecessary but an increase in the rate of sludge pumping from the secondary clarifier to primary influent is recommended. This increases the flow rate through the primary tank and assists in the prevention of lactic acid formation, which lowers the pH and interferes with the settling and digestion of sludge.

In case of accidental discharge of

milk or by-product, the waste treatment plant should be notified so that operating procedures can be modified to compensate for the increased load. Where there has been sufficient reserve capacity and high recirculation ratios, such spills have been handled successfully. Direct feed of concentrated by-products, such as whey, skim milk, and buttermilk, to municipal sludge digesters has been done without inhibiting digestion, and has resulted in increased gas production.

Milk wastes have been treated on conventional trickling filters by diluting with cooling water or effluent to provide BOD concentration to the filter of 200 to 300 ppm. However, this practice has resulted in ponding and fly nuisance. High-rate filters with recirculation ratios of 5 or 10 to 1 caused less trouble but were more expensive to operate.

Aeration may be batch or continuous, with or without return sludge. The main requirements are sufficient tank volume to give the detention necessary for the process used, proper tank shape to promote mixing, sufficient height above the waterline to contain foam, and a minimum temperature drop through the tank.

Compared with filters, aeration tanks have lower first cost and occupy less space, but more power is needed per pound of BOD removed in them, and difficulties such as foaming and sludge bulking can occur. Contrary to another popular belief, aeration tanks can take shock loads if there is sufficient reserve capacity of well-aerated sludge. Trebler claimed that this can be provided for less than the cost of equivalent filter reserve capacity. Siebert (2), reviewing experiences in Pennsylvania, found that the most common difficulty with aeration was suffocation of the sludge by excessive detention time in the settling tank and recommended returning it to the aerator as soon as possible. Clogging of diffuser orifices which are less than ⅛ in. in diameter also was frequent.

Plant Operation

Design of a treatment plant to handle waste from powdered milk production was described by Zack (3). This processing plant receives whole, skim, and condensed skim milk from farms or other dairy plants and cream is separated from the whole milk and made into butter. Before the treatment plant was built, wastes from receiving, weighing, can washing, separating, pasteurizing, and butter-making, as well as sanitary sewage, went to the village sewer; other wastes, consisting mostly of cooling water and condensate from evaporating and drying, were discharged to a creek. Overloading of the municipal plant made it necessary to provide a separate industrial waste treatment plant.

Design Data

The milk waste treatment plant design consisted of primary and secondary sedimentation, a two-stage high-rate filter, chlorination, and unheated separate sludge digestion. Also included were a Parshall flume and recording flow meter, primary and secondary recirculation pumps, and open sand sludge drying beds. It was designed for an average flow of 175,000 gpd with a 525,000 gpd maximum for 600,000 lb per day maximum milk receipts. A BOD load of 500 lb per day or 340 ppm for a population equivalent of 3,000; and 250 lb per day of suspended solids at 170 ppm with a population equivalent of 1,250 were expected.

The plant began operation in October 1955. In January 1956 it was indicated that no particularly difficult problems had been encountered. The digester was alkaline after seeding with sludge from the village plant, but biological action in the filter was slow due to cold weather. There was

an indication of short-circuiting from the primary to the secondary side of the clarifier, as evidenced by the turbid effluent. It was expected to improve when filter action became more effective, although physical changes in baffling and recirculation were considered necessary to provide added improvement.

Improvements

A stilling box was placed on the primary clarifier influent line to reduce turbulence, the baffle between the primary and secondary clarifier sections in the circular tank was lengthened, and the secondary clarifier effluent weir was raised slightly to prevent short-circuiting from the secondary to the primary. Also, a comminutor was placed on the plant influent line and the sanitary flow was diverted to the treatment works to avoid village sewer service charges. Around the comminutor pit and Parshall flume, the wall was raised about two feet to eliminate flooding when the creek rose in spring. It took several months to accomplish these changes, during which time treatment ceased.

Resumption of Operation

Poor Results

Shortly after operation was resumed, odors from the filter became evident at a distance of a fourth of a mile. Frequently, the wind carried this undesirable odor to the village business district.

During this period, the flow was erratic but averaged about 20,000 gpd. The plant effluent was cloudier than the influent, indicating that strong milk wastes were discharged in slugs rather than uniformly. The receiving stream was highly turbid along the bank below the outfall and although, through dilution and self-purification, it was relatively clear a half mile downstream, the bottom was covered with whitish fungus growths and "cotton balls" were sloughing off.

The mechanical equipment was operating satisfactorily. Growth with whitish and reddish fungus-like appearance was building up on the filter stones. A considerable amount of coagulated milk solids resembling cottage cheese was being skimmed off the clarifier surface though some was getting by the baffle and over the weir. One to five ppm of a chlorinated benzene compound was added to the plant influent for odor control, with little effect.

With an apparent flow of 20,000 gpd in a plant designed to handle 175,000 gpd, it was suspected that the long detention period and poor filter growth were permitting the waste to become anaerobic. The odor was liberated when the septic clarifier effluent was sprayed over the filters. As the small hypochlorinator available was inadequate to prechlorinate the influent effectively, it was concluded that little more could be done to reduce odor and improve plant performance during this breaking-in period.

Investigation Results

Arrangements were made with the State Health Department to collect and analyze samples from various points in the plant and stream over a 24-hr period to evaluate performance a few weeks later. The analytical results revealed other interesting facts. From influent to effluent, reduction of turbidity was 83 per cent; organic nitrogen, 70 per cent; total solids, 87 per cent; oxygen consumed, 82 per cent; and 5-day BOD, 89 per cent. The filter growths consisted largely of filamentous bacteria and algae with a few protozoa and worms.

More significantly though, the influent BOD measured was 1,575 ppm in contrast with the design value of 340 ppm. Coupled with an estimated flow of 85,000 gal, based on average head

measured at the flume, it became evident that the plant was receiving over twice the designed organic load. Furthermore, the digester supernatant which was returned to the first stage wet-well was septic. The digester supernatant contained almost 5 per cent solids with 75 per cent volatile content and had a pH of 6.3. The digester was found to be nearly filled with solids and the sludge that had been drawn dried poorly. There was now a black scum on the clarifier with attendant gassing and more solids rising to the surface.

Survey Recommendations

Of the recommendations made following the survey, the first was to determine the sources of product losses which resulted in excessive amounts of milk reaching the sewer. A further recommendation was to install heating facilities in the digester. A hot water coil was installed the following winter and by spring the digester temperature was raised to between 85 and 90°F. Also, clear plastic covers on wood frames were placed over the sludge beds for rain protection.

Further Problems and Improvements

The Parshall flume channel had been filling up with grit. The source was the tank trucks when they were washed after being emptied. This may explain Trebler's recommendation for including sand separators where they would ordinarily not be considered necessary. However, the channel was cleaned and with the end of winter highway sanding, the problem disappeared.

The digester pH was still low and sludge drying did not improve. Addition of lime raised the digester pH above 7 but did not materially improve digestion. By summer the digester was again discharging solids in the supernatant and this time it is possible that they were floated in the unagitated digester by gas bubbles. These solids accumulated in the settling tank. To prevent a recurrence of the odor problem, an old tank truck was used to remove this sludge from the clarifier. It was drawn and spread on isolated farmland until the sludge blanket was back to normal. Apparently this action relieved the digester sufficiently to permit the establishment of normal digestion because it has been satisfactory since then. Recently, processing volume has been below average though plant flows are around the design values. Unfortunately, laboratory analyses were discontinued when the plant chemist was temporarily on leave and cold weather upset operation of the samplers. However, latest influent BOD data ranged from 160 to 2,600 ppm. Final effluent BOD values have declined to as little as 40 ppm and were all less than 100 ppm during the last two months these tests were run. COD tests have been made more frequently. These have ranged between 300 and 1,300 ppm for the influent and 160 to 500 ppm for the effluent. Digested sludge solids were around 5 per cent with 50 to 60 per cent volatile solids during the same period.

Conclusions

The most important single conclusion to be drawn from these experiences is that unless the operator makes frequent tests, he does not know what he is doing and consequently is not in control of his plant. In this case the BOD overloading and build-up of solids in the digester and clarifier were not discovered until the damage had been done. Operating a sewage treatment plant consists of much more than keeping the machinery clean, oiled, and running. It involves maintaining living organisms in environments conducive to the performance of their beneficial activities. Unless the conditions affecting those environments are known and any changes detected and corrected, the functioning of the organisms is impeded resulting in the development of nuisance conditions in

the plant and pollution of the receiving stream. A good operator knows the material he is working with and the capacity of his plant to handle it.

References

1. Trebler, H. A., and Harding, H. G., "Fundamentals of the Control and Treatment of Dairy Waste." THIS JOURNAL, **27**, 12, 1369 (Dec. 1955).
2. Siebert, C. L., "Pennsylvania Milk Waste Treatment Methods." THIS JOURNAL, **29**, 9, 1038 (Sept. 1957).
3. Zack, S. I., "Trickling Filter Treatment of Wastes at Two Milk Processing Plants." THIS JOURNAL, **28**, 8, 1009 (Aug. 1956).

VI. BIOLOGICAL AND PHARMACEUTICAL WASTES

By CARL G. MAURIELLO *

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The Lederle Laboratories Division of American Cyanamid Company is a biological and pharmaceutical production plant. In the manufacturing process a wide range of raw products is handled.

As a result of the diverse manufacturing operation the wastes include a wide range of materials and characteristics. These wastes include the following:

1. Antibiotics wastes.
   a. Fermentation beers.
   b. Inorganic process solids.
   c. Floor washings.
   d. Chemical wastes.
2. Solvent recovery wastes and wash waters.
3. Animal wastes.
4. Liver products wastes.
5. Sanitary wastes.

Treatment Facilities

Treatment facilities to handle these wastes in earlier times consisted of a small activated sludge plant with the effluent discharged directly into a stream. Later facilities included a circular clarifier (40-ft diameter) followed by a high-rate trickling filter (100-ft diameter and 6-ft deep). Present facilities consist of the following units:

1. pH control.
2. Storage and aeration for 100,000 gal.
3. Three primary clarifiers (40-ft diameter).
4. Three primary trickling filters (100-ft diameter).
5. One secondary trickling filter (135-ft diameter).
6. One secondary clarifier (40-ft diameter).
7. Vacuum sludge filtration.

The physical facilities of the production plant include six pumping stations to handle an approximate flow of 0.9 mgd. The manufacturing plant consists of 150 buildings, of which 20 per cent are multi-story, on 500 acres of land, and total employment amounts to 4,500 people.

The sanitary waste is mixed with the industrial waste before treatment. Treatment plant effluent is discharged to the local sewer district.

Operation

General

One of the problems encountered in the waste treatment plant is the erratic flow pattern. As an example, the waste flow follows roughly a pattern of 50 per cent between 8 AM and 4 PM, 30 per cent between 4 PM and 12 M, and 20 per cent between 12 M and 8 AM. This flow unbalance creates erratic loading on the treatment facili-

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ties, thereby intensifying the operational problem.

The waste treatment plant at the present time is handling a total BOD load of 7,000 to 8,000 lb per day. The filter loading is about 69 lb BOD per day per 1,000 cu ft of filter volume. The total hydraulic load on the plant varies from 2.5 to 3.0 mgd. A recirculation ratio of 3:1 is used.

Odors

Odors have been a problem during the summer wherein industrial and community relations are affected. Malodors from the treatment area are intensified during humid weather, and when the winds carry the odors toward the nearby homes. One of the odor sources has been the anaerobic condition of the filters during excessive loading.

Corrective measures have been undertaken or have been considered in an effort to improve the odor problem.

One of these measures is to provide equalization of the flow to reduce the peak load to a uniform average. Holding capacity must be adequate to accomplish this. However, holding capacity should not be excessive since septic conditions within the equalization tank can be a further problem.

Recirculation of fresh waste containing some dissolved oxygen can improve the waste being held for filter application.

Another way to alleviate the problem is to aerate the fresh waste. This will help prevent the formation of septic raw waste and will begin the stabilization process.

Cooling towers provide another means of aerating the waste.

Control of Concentrated Waste

Certain of the wastes require special consideration in handling since the BOD may be extremely high. Some of these and the methods used to handle them are as follows:

1. Solvent recovery wastes. At the source these undergo pH adjustment and complete distillation.

2. Fermentation filtrate wastes. These were originally segregated and spray dried for use as animal feed supplements. At the present time these wastes are re-fermented in spare fermentors with continuous discharge to the treatment plant.

3. Intermittent discharge of small batches of deleterious material. These may include tank washings, pilot-plant wastes, or abnormal production wastes. Considerable assistance is given to the treatment plant operator if notification is given from the production department when such batches are released. Certain wastes may be handled at the treatment plant by pH adjustment or these wastes may be stored and aerated prior to complete treatment.

DIRECTORY INFORMATION NEEDED

The supplemental membership directory, to be published in the March 1959 issue of SEWAGE AND INDUSTRIAL WASTES, will contain only the data for those who have been added to the last previous complete listing (March 1958) as new or reinstated members during 1958. This supplementary listing which will include information through December 31, 1958, depends on the data being in the Federation office *by that date.*

Even though members who are listed in the 1958 directory will not appear in the 1959 listing the Federation office needs to know of job, title, or address changes, or any other change or error in a previous listing. Only with your cooperation can the membership files be kept current and accurate.

EFFECTS OF RADIOACTIVE MATERIALS ON ANAEROBIC DIGESTION *

II. RADIOIODINE

By Werner N. Grune, Donald D. Bartholomew, and Cecil I. Hudson, Jr.

Associate Professor and Research Associates, respectively, Sanitary Engineering Research Laboratory, Georgia Institute of Technology, Atlanta, Ga.

Part I of this two-part paper, containing the general description of the investigation, the methods used, and the results of P^{32} experimentation, appeared in the September 1958 issue of This Journal. In Part II the results of the I^{131} phase of the study are reported.

Experimental Results with I^{131}

Gas Production

The maximum level of activity investigated with I^{131} was 100 mc/l. Therefore, only the effects within a range of 1.0 to 100 mc/l can be reported. Figure 1 shows cumulative gas production for Run X from digesters containing plain sludge, those to which equivalent salt † was added, and those containing carrier-free I^{131}. There appears to be no significant difference in gas production between the variously treated sludges. Since the quantity of I^{131} is not detectable by chemical analysis, the addition of the salt in these sludge samples represents the composition of the solution in which I^{131} is shipped to preserve the I^{131} in the iodide form. The absence of a carrier salt simplified the studies with radioiodine considerably, because the concentrations of "preservative" were insignificant and a study of pure effects due to radiation could be more easily obtained.

The efficiency of gas production in terms of cubic feet per pound of volatile matter destroyed also showed no significant differences for the concentrations studied between the values obtained from digesters with I^{131} and those with plain sludge. For quantitative values see Table I.

Reaction Velocity Constant

Reaction velocity constants were computed for all the runs with I^{131} and the results from statistical analyses using the t-test are shown in Table II. It may be seen from this table that no significant differences were obtained with concentrations from 10.0 to 100 mc/l of I^{131} or when only the highest concentration, 100 mc/l, was compared with the plain sludge samples.

As an additional test of the relationship of k on temperature, sludge mixture, salt concentration, and concentration of I^{131}, a multiple correlation analysis from a total of 38 values yielded the following relationship:

$$k = 0.1996 - 0.00113T - 0.03637\,M + 0.000013\,S_c + 0.00012\,I_c \quad (1)$$

* Presented at 1958 Nuclear Congress; Chicago, Ill.; Mar. 17–21, 1958 (Sponsored by the Federation of Sewage and Industrial Wastes Associations).

† "Salt" in the I^{131} studies refers to a solution of 6,220 ppm $NaHCO_3$ and 5,380 ppm Na_2SO_4 added to the controls to simulate the solids in the carrier-free I^{131} solution, in accordance with the present Oak Ridge I^{131} process (1).

in which

T = temperature, °F;
M = proportion of sludge mixture, based on fresh solids;
S_c = concentration of salt solution ($NaHCO_3 + Na_2SO_3$), ppm; and
I_c = concentration of I^{131}, mc/l.

The coefficient of multiple correlation, R, was found to be 0.26, which by coincidence is the same value as that found for the P^{32} data. Correlation therefore appears to be highly non-significant. Since k-values for all gas production runs with I^{131} could be analyzed and were included in this analysis, it appears that I^{131} exerts no real effect on anaerobic digestion up to 100 mc/l of activity.

Ultimate Gas Produced

The ultimate gas volume, G, was also not significantly affected, as also shown in Table II, up to a level of 100 mc/l of I^{131}. No real differences in ultimate gas values were observed (Figure 1 or Table I).

Volatile Acids, pH, and Reduction of Volatile Matter

Without any real effect on gas production rates, and ultimate production, no significant effect on these variables was to be expected. As may be observed from Table I, the results of the I^{131} studies show that the reduction of volatile matter was not affected by the addition of I^{131} in the concentrations studied. The volatile acids concentrations did not exceed 1,000 ppm in any of the sludges during the I^{131} studies and usually was between 250 and 600 ppm at the end of the digestion period.

Typical results of continuous pH measurements during these studies are shown in Figures 2, 3, and 4, summarizing the results from digesters 14, 15, and 16 during Run XI. The variation of pH with progress of digestion was very normal, with an initial acid fer-

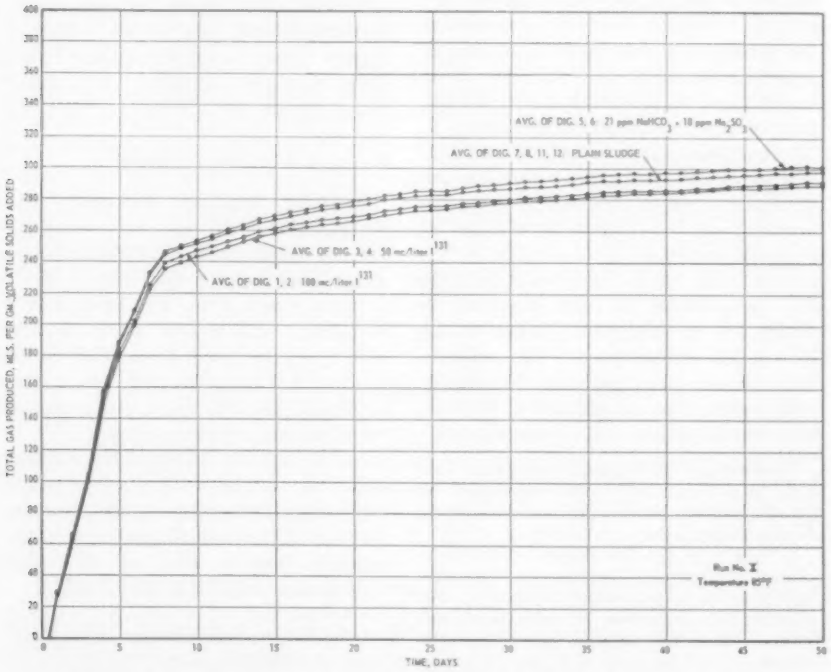
TOTAL GAS PRODUCED, MLS. PER GM. VOLATILE SOLIDS ADDED
TIME, DAYS
AVG. OF DIG. 5, 6: 21 ppm NaHCO3 + 10 ppm Na2SO3
AVG. OF DIG. 7, 8, 11, 12: PLAIN SLUDGE
AVG. OF DIG. 3, 4: 50 mc/liter I131
AVG. OF DIG. 1, 2: 100 mc/liter I131
Run No. X
Temperature 85°F

FIGURE 1.—Cumulative gas production with 50 mc/l and 100 mc/l of I^{131}.

TABLE I.—Experimental Conditions, Gas Production, and Volatile Matter Reduction for Radioiodine (I^{131}) Studies

Run	Period (days)	Date	Dig. No.	Experimental Conditions					Total Gas Production		Red. Vol. Matter (%)
				Sludge Vol. (ml)	Sludge Mixture	Inc. Temp. (°F)	Conc. of Salts* (ppm)	Conc. of I^{131} (mc/l)	Ml per g V.M. Added	Cu ft per lb V.M. Destroyed	
IX	26	8/22/57	1	1,800	1:1	85	—	13.75	161.1	12.48	20.78
		↓	2	↓	↓	↓	—	13.75	21.4	0.631	54.70
			3				5.8	—	26.0	1.953	21.44
		9/17/57	4				5.8	—	29.4	1.440	32.82
			6				—	—	101.3	3.342	48.80
			11	↓	↓	↓	—	—	53.9	2.329	37.20
X	54	10/ 2/57	1	1,400	0.8:1	85	—	100	290.0	17.84	26.03
		↓	2	↓	↓	↓	—	100	291.7	17.94	26.04
			3				—	50	292.3	24.15	19.35
		11/24/57	4				—	50	287.9	14.88	31.02
			5				39.2	—	304.4	16.06	30.33
			6				39.2	—	299.9	16.72	28.70
			7				—	—	309.3	16.87	29.38
			8				—	—	296.4	15.08	31.46
			9				19.6	—	298.4	16.16	29.57
			10				19.6	—	311.9	14.99	33.33
			11				—	—	293.4	13.23	35.50
			12				—	—	296.1	11.21	42.34
			13				—	—	240.5	21.69	17.78
			14				—	—	229.2	13.20	27.81
			15				19.6	—	263.6	15.07	27.99
			16	↓	↓	↓	—	50	†	†	†
XI	39	1/ 3/58	1	800	0.8:1	91	—	—	299.8	13.95	35.1
		↓	2	↓	↓	↓	—	—	310.9	14.47	35.1
			3				6.76	—	297.6	13.20	36.8
		2/11/58	4				6.76	—	291.8	12.50	38.1
			5				67.6	—	302.8	14.10	35.1
			6				67.6	—	311.2	14.32	35.4
			7				—	10	311.4	13.33	38.1
			8				—	10	310.5	14.29	35.4
			9				0.1‡	10	303.5	13.37	37.0
			10				0.1‡	10	301.8	12.66	38.9
			11				—	100	305.6	10.04	49.6
			12	↓			—	100	304.1	11.32	43.8
			13	1,575			—	—	208.8	10.16	33.5
			14	1,575			60	—	193.2	9.40	33.5
			15	1,575			—	9	257.7	11.99	35.1
			16	1,575			—	85	258.8	13.36	31.6
			17	800			10‡	10	193.2	7.56	41.7
			18	800	↓	↓	10‡	10	190.2	8.66	35.8

* Composition of salts: 53.6% $NaHCO_3$ and 46.4% Na_2SO_3.
† Pump line broke, spilling contents.
‡ Represents concentration of I^{127} added, in ppm, for isotopic dilution study.

mentation phase which reached its maximum on about the third day, followed by a normal rise to a buffered pH at about 7.4 to 7.5. This behavior was almost identical for all three digesters (Figures 2, 3, and 4).

Influence on Redox Potential and Liquid Conductivity

With the identical procedure used during the P^{32} studies, continuous redox potential, conductivity, and pH measurements were recorded. In con-

TABLE II.—Average Differences and Probability (P) of Their Occurrences by Chance Alone for k and G Values at Various Concentrations of I^{131} and Salt* Added to Plain Sludge

(*a*) COMPARING PLAIN AND I^{131} SLUDGES

Plain Sludge vs. I^{131} (mc/l)	Number of Digester Pairs	Values of k		Values of G	
		$\bar{d}=\frac{\Sigma(k_e-k_h)}{n}$	P (%)	$\bar{d}=\frac{\Sigma(G_e-G_h)}{n}$	P (%)
10 to 100	11	−0.0065	18.4	+6.5	47.4
10 to 50	7	−0.0106	17.5	+6.5	66.7
100	4	+0.0005	79.1	+6.5	19.2

(*b*) COMPARING PLAIN AND SALT* SLUDGES

Plain Sludge vs. Salt (ppm)	Number of Digester Pairs	Values of k		Values of G	
		$\bar{d}=\frac{\Sigma(k_e-k_s)}{n}$	P (%)	$\bar{d}=\frac{\Sigma(G_e-G_s)}{n}$	P (%)
6 to 67	12	+0.0083	35.9	+16.3	18.9

(*c*) COMPARING I^{131} AND SALT* SLUDGES

I^{131} (mc/l) vs. Salt (ppm)	Number of Digester Pairs	Values of k		Values of G	
		$\bar{d}=\frac{\Sigma(k_h-k_s)}{n}$	P (%)	$\bar{d}=\frac{\Sigma(G_h-G_s)}{n}$	P (%)
10 to 100 vs. 6 to 67	11	+0.0039	63.2	+12.5	36.7

* Solution of $NaHCO_3$ and Na_2SO_3.

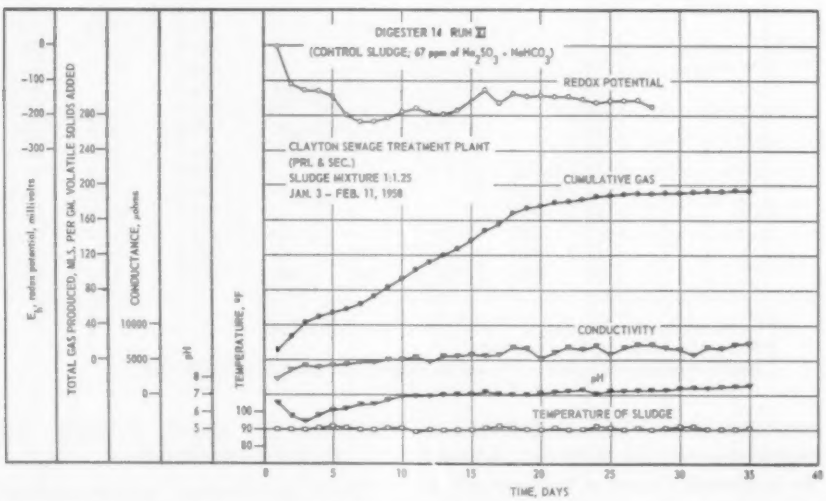

FIGURE 2.—Cumulative gas production, potentials, conductivity, pH, and temperature measured during digestion of control sludge, digester 14.

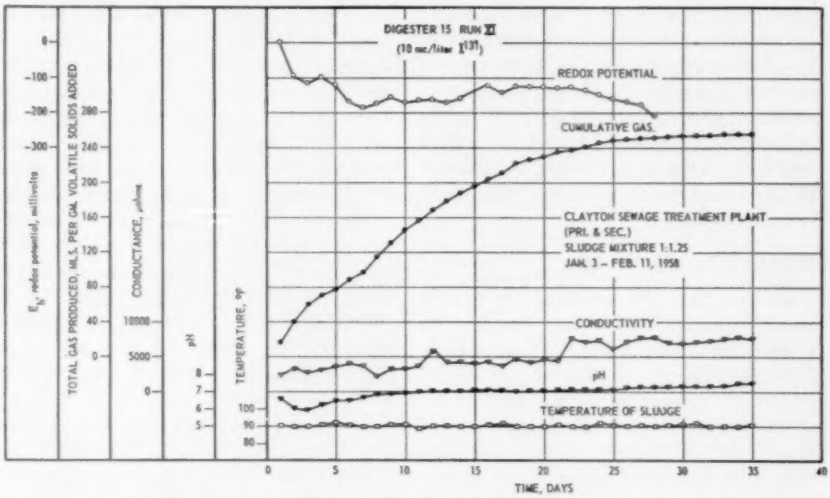

FIGURE 3.—Cumulative gas production, potentials, conductivity, pH, and temperature measured during digestion of sludge containing radioiodine, digester 15.

trast to the P^{32} studies, there appeared to be no measurable difference between the redox potentials obtained from the various digesters, regardless of whether they contained plain sludge, or sludges to which I^{131}, or sludge to which the equivalent salt solution had been added.

Figures 2, 3, and 4 (digesters 14, 15, and 16, Run XI) show typical plots of cumulative gas production, temperature, ORP, conductivity, and pH, against time in days. As can be seen from the figures there appear to be no real differences between the redox

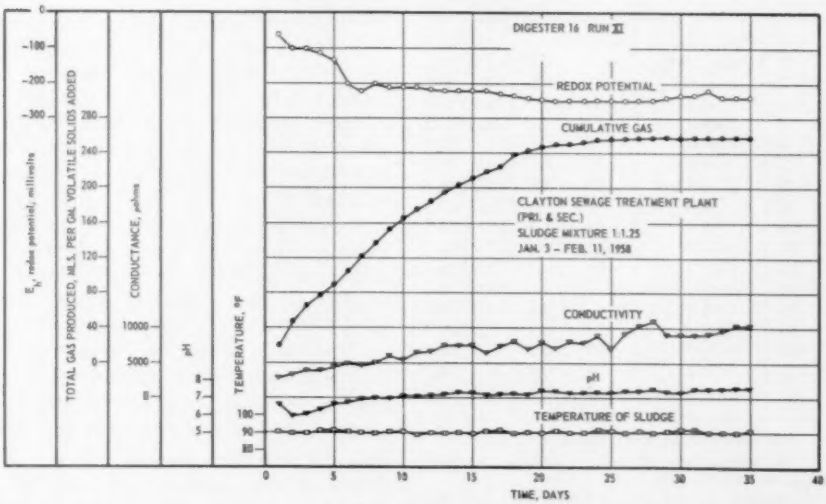

FIGURE 4.—Cumulative gas production, potentials, conductivity, pH, and temperature measured during digestion of sludge containing radioiodine (100 mc/l I^{131}), digester 16.

potentials from concentrations of I^{131} up to 100 mc/l. The conductivity, starting at approximately 2,500 μmhos, reaches a value of 10,000 μmhos for digester 16, as compared with 7,500 μmhos for digesters 14 and 15. This may be of some significance, as digester 16 produced more gas than the other two digesters.

Influence on Gas Quality

As for the P^{32} studies, chromatographic analyses of gas production were carried out for all studies with I^{131}. Samples from each of the 16 digesters were analyzed and a typical set of results from samples analyzed every day to follow changes in gas composition with digestion progress, is shown in Figure 5. Because at the time of these analyses a 12-ft silica gel column was used and a higher temperature employed, the calibration curves to interpret Figure 5 are reproduced as Figure 6. This particular set of analyses was made on the 9th day of Run XI and showed that for batch digesters methane production was approximately 72 per cent, the carbon dioxide about 27 per cent, with approximately 1 per cent air, regardless of whether the gases of decomposition from plain sludge, sludge to which I^{131}, or sludge to which the salt solution had been added, were considered. A typical gas analysis for each digester used in Run XI is shown in Table III. From the composition of the digester gas in terms of carbon dioxide content (Figure 7), it is apparent again that there was no difference in the quality of gas produced from any of the digesters.

For recirculated digesters (digesters 12 through 16) the relative percentages of CH_4 and CO_2 were different. Almost 80 per cent of the gas was methane and slightly more than 20 per cent was carbon dioxide. This does not hold true for digester 13, which had even less methane than the batch digesters, and a higher CO_2 content than any of the other digesters in Run XI. However, this digester behaved quite differently in many other respects, as demonstrated by the k-value, which was also much lower than for any other digester in this run. The reason for the erratic behavior of digester 13 could not be determined. The higher relative methane composition for the other three recirculated digesters is in accordance with the practice of recirculation (2).

It is of considerable interest to note, however, that there seems to be no effect on the gas quality in the presence of I^{131} in concentrations up to 100 mc/l. Since gas quality has been recognized as a sensitive barometer of digestion and further substantiated by the application of chromatographic analysis, it seems to definitely indicate that the digestion process was not affected in these studies.

A determination of gross beta and gamma activity in the gas phase of a

TABLE III.—Qualitative Gas Analyses from 18 Digesters[a], Run XI

Dig. No.	Concentration of Salts[b] (ppm)	Conc. of I^{131} (mc/l)	Percentages by Volume		
			Air	CH_4	CO_2
1	Plain sludge	—	1.3	72.3	26.4
2	Plain sludge	—	0.8	72.7	26.5
3	6.8	—	0.9	72.6	26.5
4	6.8	—	1.5	71.1	27.4
5	68.0	—	1.1	71.8	27.1
6	68.0	—	0.9	71.8	27.3
7	6.8	10	0.8	72.0	27.2
8	6.8	10	1.0	72.2	26.8
9	6.8[c]	10	1.3	71.5	27.2
10	6.8[c]	10	1.5	72.8	26.7
11	68.0	100	0.1	72.2	27.7
12	68.0	100	1.3	72.0	26.7
13	Plain sludge[d]	—	1.8	69.6	28.6
14	68.0[d]	—	0.5	79.0	20.5
15	6.8[d]	10	0.4	79.2	20.4
16	68.0[d]	100	0.2	79.2	20.6
17	6.8[e]	10	0.2	73.3	26.5
18	6.8[e]	10	0.1	73.4	26.5

[a] Analyses from 10th day of Run XI.
[b] Combination of salts: 53.6% $NaHCO_3$ and 46.4% Na_2SO_3.
[c] Added also 0.1 ppm I^{127}.
[d] Sludge recirculated.
[e] Added also 10.0 ppm I^{127}.

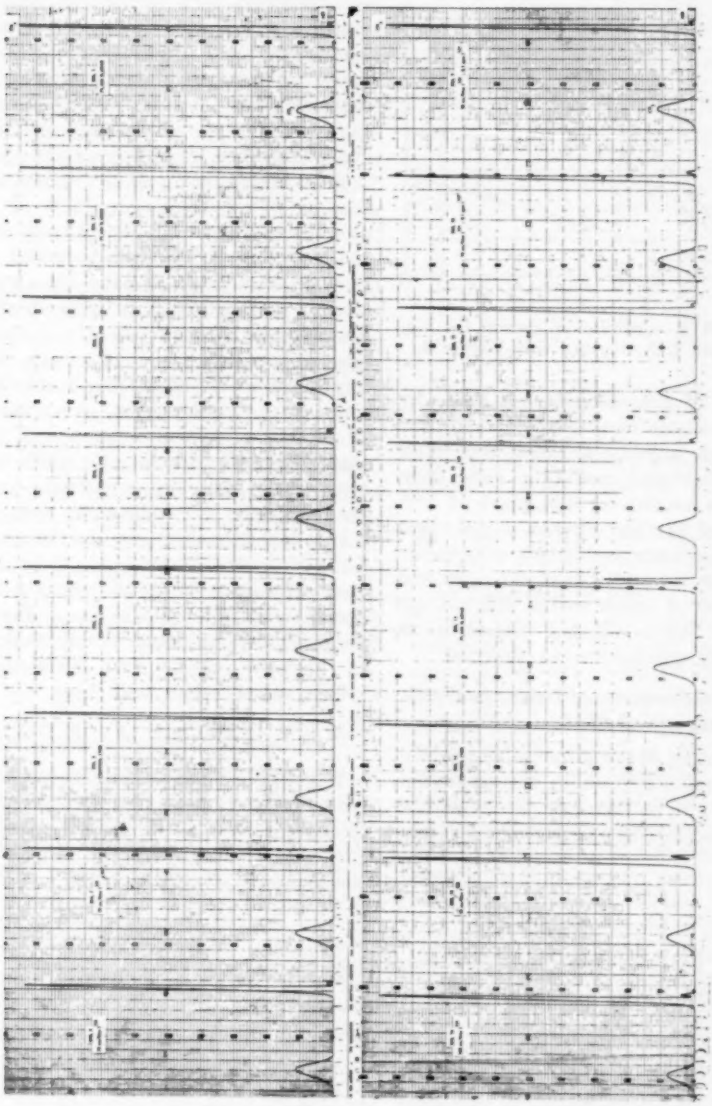

FIGURE 5.—Gas chromatographic analysis of sludge gases, Run XI, I^{131} (10th day, Jan. 12, 1958); column, 12 ft silica gel, 28–48 mesh; flow rate, 80 ml/min; sample size, 1.5 ml; column temperature, 130°F.

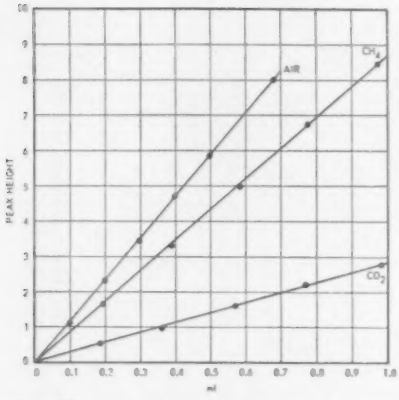

FIGURE 6.—Calibration curves for air, CH_4, and CO_2; for use with Figure 5.

number of gas samples was made by the techniques used in the P^{32} studies. Maximum activity detected was twice the background counting rate from digesters containing 100 mc/l of I^{131}.

It is of further interest to note that a study of isotopic dilution with radioiodine by the addition of 0.1 ppm and 10.0 ppm of stable iodine did not appear to have affected digestion as shown by qualitative gas analyses.

Natural Occurrence of Iodine in Water, Sewage, and Sludge

According to the National Committee on Radiation Protection, the concentration of I^{131} in drinking water should not exceed 3×10^{-5} μc/ml, which means 136 millicuries per million gallons of water. Thus, it seems unlikely that natural waters would normally become contaminated with I^{131} to this extent. But it is conceivable that under certain conditions such contamination could arise. It was therefore of interest to determine the fate of radioiodine during processes normally employed for the purification of waste waters.

Radioactive isotopes of iodine are present in the fission products of an atomic explosion. Meinke (3) reported the presence of radioactive iodine in snow in New England after the explosion of atomic bombs in New Mexico. To predict the behavior of a radioactive substance in water or sewage, it is important to know whether stable isotopes of the same element are present. If the added radioisotopes are of the same chemical form as the stable isotopes of the same element already present in solution, the radioactive material will follow the same chemical reactions. This is generally referred to as isotopic dilution. If stable isotopes are present in solution in a different chemical form, exchange reactions, such as between iodide and elementary iodine, shown below, will occur.

$$I^{-131} + I_2 \rightleftarrows (I^{131} \cdot I_2)^- \rightleftarrows (I^{131} \cdot I) + I^-$$

Physical exchange reactions may also occur between iodide in solution and iodide adsorbed on surfaces in contact

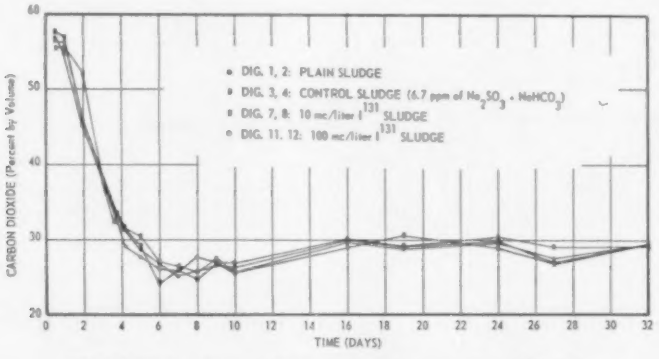
DIG. 1, 2: PLAIN SLUDGE
DIG. 3, 4: CONTROL SLUDGE (6.7 ppm of Na_2SO_3 + $NaHCO_3$)
DIG. 7, 8: 10 mc/liter I^{131} SLUDGE
DIG. 11, 12: 100 mc/liter I^{131} SLUDGE
CARBON DIOXIDE (Percent by Volume)
TIME (DAYS)

FIGURE 7.—Composition of digester gas, Run XI, I^{131}.

with the solution. The rate of exchange between atoms in different states of chemical combination depends on the actual conditions. Friedlander and Kennedy (4) reported the exchange reaction between the iodide and iodate ions in alkaline solution is extremely slow. Murray *et al.* (5) published data showing the concentration of total iodine in 81 samples of drinking water in England varied from 0.001 to 0.050 ppm. It is not clear whether some or all of this iodine was present in the form of iodide. Eden *et al.* (6) used a natural water believed to contain about 0.006 ppm of iodine.

It may be of some interest that the radioiodine employed in the experiments described was formed by the fission of uranium in the ORNL graphite reactor, and since no carrier was added, iodine was not detectable by chemical analysis (less than one μg/ml, or one ppm). Inasmuch as the maximum volume of this solution added in any of the experiments with I^{131} did not exceed 6 ml per liter of sludge, the maximum concentration of I^{131} artificially added could not have exceeded 0.005 ppm.

To reach any conclusions on the mechanism of I^{131} uptake, caused by the exchange of iodine in solution with iodine in suspended algae or biota, it is first necessary to establish the quantity of stable iodine present initially. For this purpose an analytical technique measuring the color change during reduction of the ceric to the cerous ion by spectrophotometric means was devised. The oxidation proceeds depending on the quantity of iodine catalyst present; therefore, the rate of reaction is a measure of the concentration of iodine present.

The analysis of sludge from six digesters containing no added iodine showed that the average normal iodine concentration for this particular domestic sludge (Clayton plant, Atlanta, Ga.) was approximately 0.3 ppm.

The results of iodine analyses on the contents of digesters 1 through 18 are summarized in Table IV.

TABLE IV.—Occurrence of Iodine in Sewage Sludge, Run XI

Dig. No.	Conc. of Na_2SO_3 and $NaHCO_3$	Conc. of I^{127} (me/l)	Iodine (ppm)
1	Plain sludge only	—	0.33
2	Plain sludge only	—	0.33
3	6.7	—	0.30
4	6.7	—	0.21
5	67.0	—	0.37
6	67.0	—	0.40
7	6.7	10	0.18
8	6.7	10	0.33
9	6.7*	10	0.44*
10	6.7*	10	0.44*
11	67.0	100	0.38
12	67.0	100	0.30
17	6.7†	10	9.92†
18	6.7†	10	9.90†

* 0.1 ppm I^{127} added at beginning of run.
† 10 ppm I^{127} added at beginning of run.

Distribution of Radioactivity between Solid and Liquid Component

As discussed in Part I, it was considered necessary to determine the radioactivity of the solid and liquid phases of the end products of digestion. The terms, solid and liquid component, as applied to this study were previously defined, as well as the technique used for their determination. The major difference in analytical technique was that a gamma spectrometer * was used to count the I^{131} samples, thereby greatly facilitating the work. The results are shown in Figures 8 and 9. It appears from Figure 8 that there may be a decrease in the relative amount of I^{131} in the solid phase with an increase of initial concentrations of I^{131}. It also appears that 60 per cent or more of the activity is retained by the solid phase. The functional relationship existing appears to be:

$$\frac{A_S}{A_L} = 86.3 - 8.3 \log A_0 \quad \ldots (2)$$

* Model DZ 46, Automatic Gamma Ray Spectrum Recorder, manufactured by Detectolab, Inc.

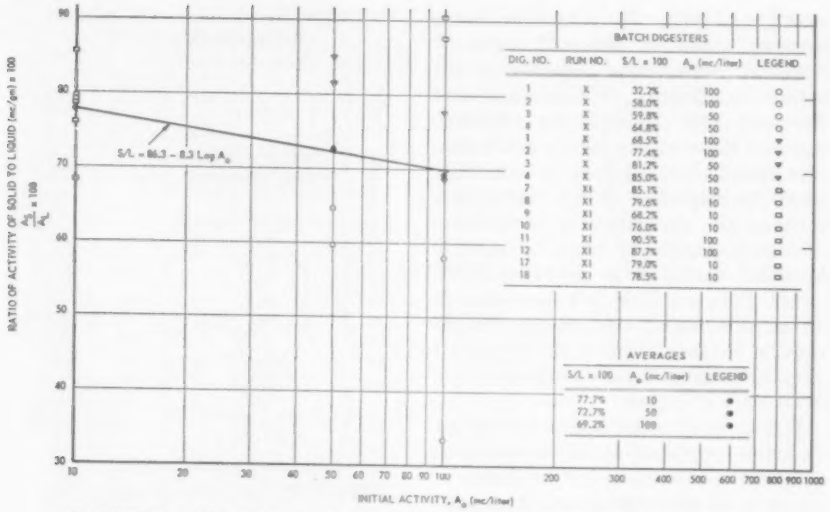
BATCH DIGESTERS
DIG. NO. RUN NO. S/L x 100 A_0 (mc/liter) LEGEND
1 X 32.2% 100
2 X 58.0% 100
3 X 59.8% 50
4 X 64.8% 50
1 X 68.5% 100
2 X 77.4% 100
3 X 81.2% 50
4 X 85.0% 50
7 XI 85.1% 10
8 XI 79.6% 10
9 XI 68.2% 10
10 XI 76.0% 10
11 XI 90.5% 100
12 XI 87.7% 100
17 XI 79.0% 10
18 XI 78.5% 10
AVERAGES
S/L x 100 A_0 (mc/liter) LEGEND
77.7% 10
72.7% 50
69.2% 100
S/L = 86.3 - 8.3 Log A_0
RATIO OF ACTIVITY OF SOLID TO LIQUID (mc/gm) x 100
$\frac{A_S}{A_L}$ x 100
INITIAL ACTIVITY, A_0 (mc/liter)

FIGURE 8.—Distribution of I^{131}-activity between solid and liquid phases.

in which

A_S = activity of solid phase, mc/g;
A_L = activity of liquid phase, mc/g; and
A_0 = initial activity of sludge mixture, mc/l.

Figure 9 shows the proportion of activity removed from the liquid, expressed as percentage of the initial total activity of the sludge mixture, plotted against initial activity, A_0. In Figure 9, A_t represents final activity

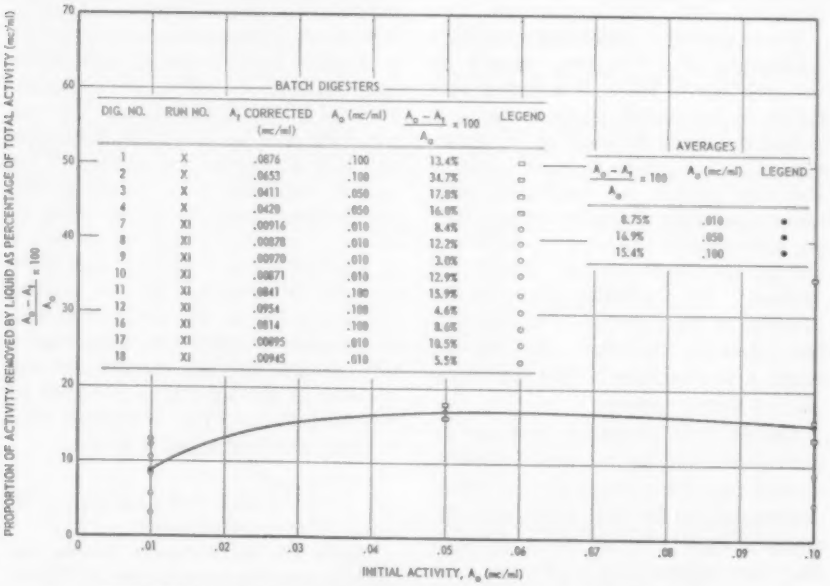
BATCH DIGESTERS
DIG. NO. RUN NO. A_t CORRECTED (mc/ml) A_0 (mc/ml) $\frac{A_0 - A_t}{A_0}$ x 100 LEGEND
1 X .0876 .100 13.4%
2 X .0653 .100 34.7%
3 X .0411 .050 17.8%
4 X .0420 .050 16.0%
7 XI .00916 .010 8.4%
8 XI .00878 .010 12.2%
9 XI .00970 .010 3.0%
10 XI .00871 .010 12.9%
11 XI .0841 .100 15.9%
12 XI .0954 .100 4.6%
16 XI .0814 .100 8.6%
17 XI .00895 .010 10.5%
18 XI .00945 .010 5.5%
AVERAGES
$\frac{A_0 - A_t}{A_0}$ x 100 A_0 (mc/ml) LEGEND
8.75% .010
14.9% .050
15.4% .100
PROPORTION OF ACTIVITY REMOVED BY LIQUID AS PERCENTAGE OF TOTAL ACTIVITY (mc/ml)
$\frac{A_0 - A_t}{A_0}$ x 100
INITIAL ACTIVITY, A_0 (mc/ml)

FIGURE 9.—Proportion of I^{131}-activity removed from liquid phase.

of the separated liquid phase only. The plot indicates that as initial activity increases from 10 to 100 mc/l the relative concentration in the liquid phase increases only slightly, from 8 to 17 per cent. It is pointed out that these studies represent a narrower range of activity than did the P^{32} investigations. Work is continuing with higher concentrations. However, it is believed that even 100 mc/l is a concentration of I^{131} which will not be exceeded in a digester in the foreseeable future, if ever.

The precautions mentioned in Part I regarding the activity associated with the liquid when a "solid" sample is prepared for counting apply equally well here.

Summary and Conclusions

On the basis of these investigations on the effects of radioactive wastes containing I^{131} in concentrations up to 100 mc/l the following conclusions may be drawn:

1. The rate of gas production from similarly prepared seeded mixtures with or without I^{131} was not significantly altered up to 100-mc/l concentrations. The same holds true for those digesters which received the equivalent "preservative" salt solution, composed of $NaHCO_3$ and Na_2SO_3, which was used as the control, although the radioiodine was carrier-free.

2. The ultimate gas production, volatile acids concentration, reduction of volatile matter, and pH, were not significantly affected in the presence of I^{131} in concentrations up to 100 mc/l.

3. The redox potential obtained from digesters with and without I^{131} showed no significant difference. The ORP technique holds promise as a tool for digester studies.

4. The gas quality in the presence of I^{131} was not affected. The relative concentration of methane and carbon dioxide was 72 and 27 per cent, respectively, for all types of sludge on the ninth day of the experiment.

5. There appears to be no significant change in the uptake of I^{131} by the solid phase with increases in initial radioactivity up to 100 mc/l. At least 60 per cent of the activity appears to be concentrated in the solid phase. This degree of concentration suggests some promise of fixing a portion of radioactivity in sewage sludge solids for low-level disposal. Further investigations to explore the leachability of activity from these solids, with and without the addition of admixtures and fluxes, should be undertaken to determine the value of sludge for decontamination.

Acknowledgments

The authors are indebted for the assistance of a number of colleagues and assistants who were associated with various phases of this research program. Professors J. M. DallaValle, I. Grovenstein, and W. T. Ziegler, gave freely of their time; Dr. Wm. F. Atchison and Professor J. W. Walker, of the Rich Electronic Computer Center, analyzed the data for multiple correlation. Much credit is due to Chun-fei Chueh, Roy C. Peek, Jr., and Iraj Zandi, research associates, as well as Bruce Bundsen, John W. Cameron, James V. Carter, Jr., Jimmy G. Lee, Sang S. Park, and Marvin A. Turner, research assistants, who carried out most of the laboratory investigations. Many others on the staff of Georgia Institute of Technology, too numerous to mention, gave freely of their time during these investigations.

The authors are also indebted to a number of industrial organizations without whose splendid cooperation, technical advice, and service, these studies would not have been possible. Several instruments were made available for the continuous measurement of a number of variables. The Foxboro Company provided electronic recorders for redox potentials and liquid

and thermal conductivity; Industrial Instruments, Inc., provided a conductivity bridge and a four-point recorder for conductivity; the Brown Instruments Division of Minneapolis-Honeywell Regulator Company loaned a six-point pH recorder; Beckman Instruments, Inc., loaned a redox potential flow-cell and amplifier; Fischer & Porter Company cooperated in many ways by supplying ORP cells, flow meters, a redox potential and temperature recorder; the Wheelco Instruments Division of Barber-Colman Company provided a strip-chart recorder for chromatographic gas analysis studies.

The research reported herein was sponsored by several agencies. Low-level isotope studies were sponsored by the National Science Foundation; high-level studies were supported by the U. S. Atomic Energy Commission and the Engineering Experiment Station of Georgia Institute of Technology. The work on gas chromatography was sponsored by the National Institutes of Health. Without financial support from these agencies these investigations could not have been carried out.

References

1. Personal communication from H. Blauer, Union Carbide Nuclear Co., Oak Ridge National Lab., Oak Ridge, Tenn. (Aug. 15, 1957).
2. Walker, J. D., "Sludge Digestion and Methane Production." *Sewage Works Jour.*, **20**, 3, 544 (May 1948).
3. Meinke, W. W., "Observations on Radioactive Snows in New England." *Science*, **113**, 545 (1951).
4. Friedlander, G., and Kennedy, J. W., "Introduction to Radiochemistry." p. 282, John Wiley and Sons, New York, N. Y. (1949).
5. Murray, M. M., Ryle, J. A., Simpson, B. W., and Wilson, D. C., "Thyroid Enlargement and Other Changes Related to the Mineral Content of Drinking Water." Med. Res. Council Memo. No. 18, H. M. Stat. Off., London (1948).
6. Eden, G. E., *et al.*, "Observations on the Removal of Radioisotopes During Purification of Domestic Water Supplies. I. Radioiodine." *Jour. Inst. Water Engrs.* (Brit.), **6**, 511 (Nov. 1952).

CORRECTION

In the paper, "Effects of Radioactive Materials on Anaerobic Digestion. I. Radiophosphorus," by Werner N. Grune, Donald D. Bartholomew, and Cecil I. Hudson, Jr. (THIS JOURNAL, **30**, 9, 1123; Sept. 1958), under "Drinking Water," in Table I, the allowable concentration of Y^{91} should be 2×10^{-1} μc/ml and 8×10^{-1} mc/gal; the allowable concentration for $Ru^{106} + Rh^{106}$ should be 1×10^{-1} μc/ml and 4×10^{-1} mc/gal.

Stream Pollution

EFFECTS OF FERTILIZATION ON RECEIVING WATERS*

By James B. Lackey

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In 1908 Letts and Adeney (1) reported on the pollution of estuaries and tidal waters by sewage and trade wastes in Ireland and Great Britain. This report relates the destruction of salmon and sea trout fisheries, caused by the growths of vast beds of the macroscopic green alga, *Ulva*, and its subsequent decay. That decay produced intolerable odors, blackened paint and silver in homes, and generally was damaging to real estate values.

In the 50 intervening years since the researches of these two men, much has been learned about sewage treatment and the necessity for it. Nevertheless, there are cities which today do not have sewage treatment, others which partially treat sewage, and still others which are lax in their enforcement. A clean stream or harbor should not have a BOD of greater than four parts per million. Most people who understand such matters do not need to be reminded of the harmful effects of untreated sewage on a receiving water. Today, however, there is more and more heard about a shortage of usable water and the question inevitably arises: What are the effects of returning *any* used water and in what condition may it be returned? This discussion deals with the first part of that question directly and indirectly with the second part.

Fertilization of Natural Waters

It has been well established that raw sewage or the effluents of sewage treatment plants contribute fertilizer in the form of nitrates and phosphates to a receiving water (2)(3)(4)(5)(6)(7)(8). What is less emphasized is that there are other growth promoting substances in such effluents. Among them are trace elements, hormones, and vitamins. The sum total of these additions frequently results in a highly productive receiving water. Such waters are said to be eutrophic, a term familiar to the biologist but less so to the engineer. Sewage effluents represent a balanced fertilizer, although too much in a stream is as bad as too much fertilizer in a garden.

Introduction of trade wastes may seriously interfere with this balance. Washings from a sand pit or gravel quarry, while providing nitrates and phosphates leached from the soil, also add blanketing quantities of silt—a physical interference. Chromium wastes may cause an upset of a toxic nature while another waste may add too much phosphorus or too much of some other component and alter the nutrient ratios favorable for some organisms.

The nature and effect of raw or treated domestic sewage when admitted

* Presented at the Annual Meeting of the Florida Sewage and Industrial Wastes Assn.; Jacksonville, Fla.; Nov. 11–13, 1957.

to a natural water is fairly well understood. However, each trade waste represents almost an individual problem, largely because the specific requirements for growth of many organisms are not known. A single case will illustrate the point. Fogg and Westlake (9) have found that the blue green alga, *Gleotrichia natans*, will grow only if detectable soluble phosphate is removed from the medium. This alga, in its rare blooms, is highly objectionable. Obviously a waste containing a complexing agent for soluble phosphate would tend to favor the growth of *Gleotrichia*. Information such as this is the result of tedious research, too often unknown to the sanitary engineer who is evaluating the results of treating or admitting a trade waste to a receiving water. These experiences point to the necessity for collaboration with a biologist.

Evaluation of Fertilization Effects

Another matter which should be evaluated in considering any individual case of admitting a waste to a stream or other body of water, is the balance of resulting effects against benefits to the waste producer. Generally speaking, there are three recognized benefits, at least from sewage, due to algal growths. These are: (a) reoxygenation, (b) mineralization, and (c) production of a food chain. There are also three well recognized ills resulting from such growths. These are: (a) algal toxicity, (b) aesthetic harm, such as a soupy appearance, taste and odors in potable water, and odors from algal decomposition, and (c) buildup of a biochemical oxygen demand.

In connection with these pros and cons, several considerations need discussion. Reoxygenation and mineralization need little comment, although it is pertinent to note that reoxygenation is probably necessary simply because a first effect of the waste might have been deoxygenation. Production of a food chain is another matter. It cannot be assumed that any alga is, ultimately, food for an organism useful (as food) for man. It is true that, lacking a sewage effluent or being psychologically opposed to its use, frequently commercial fertilizer is used to produce plankton in ponds, with a hope for a fish crop. The results may vary from deoxygenation, with a fish kill, to an over-abundant crop of practically useless small fish. There is ample evidence (10) that intermediate organisms in the food chain feed selectively and that the food chain is easily broken. Careful management is, therefore, needed.

Toxic Effects

Production of the wrong kind of algal crop may have serious adverse effects. Oysters are a prime food for man and one of the finest oysters was the former Blue Point, produced in Great South Bay, Long Island. Oysters are algal feeders. After the oyster industry was well established in Great South Bay, the Long Island duck industry located around the Bay. The duck excreta at once began to fertilize the Bay. A heavy algal bloom resulted but the algae were not suitable food, or they produced external metabolites which adversely affected the oysters. An annual four million dollar industry was thus completely destroyed (11). Not until corrective measures were initiated for the duck farm wastes has there been an indication that oysters may return as a profitable harvest for this area. In addition, fishing, crabbing, clamming, boating, and bathing were adversely affected by the algal bloom, which generally appeared in the spring and lasted throughout the summer—quite unlike most algal blooms.

The Florida Gulf Coast red tide is an example of a fish-killing algal bloom, although the cause of this bloom is not known at present. Certainly it is not sewage, but there have been suggestions, generally regarded as untenable, that phosphate mining wastes might be

a factor. The toxic effects of algae have been cited for many other algae than *Gymnodinium brevis* which constitutes Florida's Red Tide. *Prymnesium* is another fish killer, and several blue-green algae are said to be directly toxic to cattle, although the matter is still being debated in the literature. In no case has sewage pollution been referred to, but for *Prymnesium* the fertilization of fish ponds containing chlorides in excess of 250 ppm produced the blooms (12). It is evident that in those stock watering ponds producing toxic blue-greens there is fecal pollution of the pond by the cattle.

These are direct toxic effects. Indirect toxic effects are not limited to anaerobiosis from overproduction of algae. Undocumented statements concerning duck poisoning indicate that algal blooms, on decaying and forming a sludge, produce a good medium for the growth of *Clostridium botulinum*, which in turn kills waterfowl. Since a sewage effluent has not been incriminated in any of the above instances, they at first appear outside the scope of this discussion. However, enrichment of the environment by a sewage effluent could just as well cause some of the above blooms, or similar ones, and it is well to be aware of such possible situations.

Aesthetic and Physical Effects

Psychological and aesthetic effects extend to such matters as refusal to use a sewage-fed water for bathing or other recreational purposes. There are few people who will bathe in, fish in, or boat for pleasure in a "scummy," i.e., algae-laden lake or river. The truth is that man prefers an oligotrophic water for his recreation. An oligotrophic water is one of low productivity and these are frequently clear and in common parlance "pure." Admitting sewage or sewage effluents sooner or later changes such a stream or lake from an oligotrophic to a eutrophic situation. The Wisconsin lakes studies of Lackey and Sawyer (13) were made because the property owners around the lakes in question in effect claimed that city sewage was making their lakes eutrophic. Lake Washington at Seattle (14) is another such case and several others could be cited.

The growing concern over eutrophication of natural waters is well founded. Modern sewage treatment plants do an excellent job of removing solids and possible pathogenic organisms as well as clarifying the effluents, but this same effluent is still an excellent substrate for plant growth. It might be pointed out in passing that the plants are not necessarily algae—Lohmeyer (15) uses water hyacinths to reduce the amounts of available nitrogen and phosphorus in the sewage lagoons at the University of Florida and extremely heavy and luxuriant stands of water hyacinth are present along the Peace River which drains the Florida phosphate-producing area. Purdy (16) attributed the heavy growths of aquatic plants in the Potomac below Washington partly to the sewage of that city.

The algae themselves, if over abundant, can be objectionable in many ways. Small green algae such as *Chlorella, Stichococcus, Scenedesmus,* and a number of others produce the turbidity objectionable to recreation. Many blue-green algae produce mucilaginous envelopes which harbor bacteria and may protect coliforms and possibly pathogens such as *Salmonella* from chlorination, if the water is treated to render it potable. The whole algal crop can be so heavy as to increase greatly the cost of filtration and coagulation. Thus, the White River below Indianapolis, on the basis of current studies, is in warmer months producing an extremely heavy suspended microbiota which is difficult to treat by the downstream communities.

Oxygen Use Effects

Two other less well known effects of such heavy algal crops are concerned with oxygen use. Such crops of photosynthetic forms quickly produce supersaturation in the daylight hours and oxygen depletion at night. These are extremes of environment and few animals tolerate such quick changes to extremes, either moving from the area if possible (avoiding reaction) or being killed. This situation, however, is not as bad as that resulting from the death of the algal crop. Not infrequently an algal crop dies quickly, perhaps from a toxic level reached by its own excreted metabolites. When it does, oxygen depletion is fast and there is no replacement from photosynthesis. Fisheries literature contains many instances of kills due to such conditions.

In such cases, the dead algal cells exert a more lasting effect by their biochemical oxygen demand. The protoplasm and stored food reserves are attacked quickly but the cellulose cell walls are more resistant and, hence, the demand is exerted over a longer period of time. Green algae growing in sewage in an experimental lagoon at the University of Florida had a BOD of 77.8 ppm in five days. It is not often that an algal crop of this density occurs, unless in a heavily enriched situation. These algae, harvested from 500 ml of water, produced a dry weight of 0.0848 grams. Since virtually all the algae were *Micractinum,* no diatoms were present and no other organisms were present in abundance, practically all this dry weight represented protoplasm, cellulose, and starch. Evidently a crop like this merely extends the time over which the BOD is exerted, although it must be stated that there are other effects of the algal crop which are helpful, such as reduction in bacterial numbers, etc.

Bacterial Reduction

On *a priori* grounds, it seems improbable that an algal crop might be effective in reducing the bacterial population, but in actuality there are two ways in which this may be done by algae. Krauss (17) states that *Chlorella* metabolizes as a phototropic organism in the light, but in the dark it obtains energy from reduced carbon compounds. That is, it competes with bacteria for food. This single instance could be multiplied many times for other algal species, especially the Euglenophyceae. The other mechanism lies in the production of antibiotic substances which is known to occur *in situ* for some algae. Field work on the effectiveness of bacterial reduction by this process is poorly documented, but is known. Thus, Allen and Smith (18) considered that sewage effluents contain bactericidal substances but did not account for them. Ingram and Prescott (19) listed 36 references to toxic algae (virtually all blue-greens) while Otterstrom and Nielsen in 1939 (20) reported on fish mortality due to *Prymnesium parvum* which is now known to produce an exotoxin. A large number of references to antibiotic properties of algae could be cited.

Growth Species

The algal blooms from sewage treatment effluents are usually small green algae—Chlorophyceae. This is because the contribution is generally inorganic (PO_4 and NO_3) rather than organic. If the sewage flow stops, the bloom quickly dies out. Nevertheless, as long as the nutrient supply continues, the bloom can be heavy enough to be a nuisance. This has led to attempts at removal of the phosphate in Wisconsin (21) and Norway (22) as a means of preventing blooms. A controlled flora and fauna is certainly highly desirable but, if such blooms could be economically harvested, as in the many attempts to grow and harvest *Chlorella,* there might be decided benefits. Singh (23) points out that most of the blue-green algal blooms in India are due to

organic fertilization, alkalinity, etc., and are more useful for fish culture and fertilizer, if harvested, because their phosphorus content is 2 to 3 per cent and nitrogen, 12 to 20 per cent on a dry weight basis; whereas *Chlorella* has only 3 to 4 per cent nitrogen on a dry weight basis.

Most of the work in this country has centered on *Chlorella*, partly because it is so ubiquitous as to grow anywhere and partly because it is generally considered as the alga common to sewage effluents. The latter is not the case—careful observation will show other Chlorophycean species to grow equally well. It might be well to experiment with other algae such as *Glenodinium cinctum*, whose oil content is 25 to 33 per cent on a dry weight basis; or with *Spirogyra*.

Other Growth

As mentioned above, not all the blooms in fertilized water consists of algae. Besides water chestnut and water hyacinth, water lettuce (*Pistia stratiotes*), *Riccia*, *Lemna*, *Wolffia*, and *Azolla*, as well as a few other macrophytes, will grow abundantly in such situations. All have the same effects —they shut off light, exclude oxygen, interfere with boating, bathing, and swimming, exclude fish, and use up the nitrates and phosphate. Fish leave such an area and boats often find it impenetrable.

Summary

On the whole, the ill effects from the admission of sewage treatment plant effluents to receiving waters may seem to outweigh the benefits. Perhaps what is needed is treatment so complete as to remove all nitrogen, or all phosphorus. Or perhaps there is a need for some method of measuring the quantity of nutrients a receiving water can absorb without excessive ill effects. It may then be possible to design treatment based on the capabilities of the stream growths to provide for reoxygenation, mineralization, pH adjustment, suitable environment for fish, no secondary buildup of BOD, and turbidity control.

References

1. Letts, E. A., and Adeney, W. E., "Pollution of Estuaries and Tidal Waters." Appendix VI, Fifth Report, Royal Commission on Sewage Disposal. H. M. S. Stationery Office, London (1908).
2. Flett, L., and Hoyt, L. F., "Detergent Compounds—Their Composition and Behavior." THIS JOURNAL, **25**, 3, 245 (Mar. 1953).
3. Davis, C. C., "A Preliminary Study of the Plankton of the Cleveland Harbor Area, Ohio. II. The Distribution and Quantity of the Phytoplankton." *Ecol. Monographs*, **24**, 321 (1954).
4. Grau, C. R., and Klein, N. W., "Sewage-Grown Algae as a Feedstuff for Chicks." Report of Algae Project, San. Engr. Res. Lab., Univ. of California (1957).
5. Damann, K., "Missouri River Basin Plankton Study, 1950." Federal Security Agency, USPHS Environmental Health Center, Cincinnati, Ohio (1951).
6. Hasler, A. D., "Eutrophication of Lakes by Domestic Drainage." *Ecology*, **28**, 383 (1947).
7. Forbes, S. A., and Richardson, R. E., "Studies on the Biology of the Upper Illinois River." *Bull. Ill. State Lab. of Natural Hist.*
8. Tarzwell, C. M., and Gaufin, A. R., "Some Important Biological Effects of Pollution Often Disregarded in Stream Surveys." *Proc. 8th Ind. Waste Conf.*, Purdue Univ., 295 (1954).
9. Fogg. G. E., and Westlake, D. F., "The Importance of Extracellular Products of Algae." *Proc. Internat. Assn. Theoret. Appl. Limnol.*, Stuttgart, **12**, 219 (1955).
10. Nelson, P. R., and Edmondson, W. T., "Limnological Effects of Fertilizing Bare Lake, Alaska." *Fish. Bull. U. S. Fish and Wildlife Service*, **56**, 102 (1955).
11. Lackey, J. B., Vanderborgh, G., Jr., and Glancy, J. B., "Plankton of Waters Overlying Shellfish Producing Grounds." *Proc. National Shell Fish. Assn.* (1949).
12. Shilo, M., and Shilo, M., "Control of the Phytoflagellate, *Prymnesium parvum*."

Proc. Internat. Assn. Theoret. Appl. Limnol., Stuttgart, **12**, 233 (1955).

13. Lackey, J. B., and Sawyer, C. N., "Plankton Productivity of Certain Southeastern Wisconsin Lakes as Related to Fertilization. I. Surveys." *Sewage Works Jour.*, **17**, 3, 573 (May 1945).
14. Edmondson, W. T., Anderson, G. C., and Peterson, D. R., "Artificial Eutrophication of Lake Washington." *Limnol. and Oceanog.*, **1**, 1, 47 (1956).
15. Lohmeyer, G. T., Personal Communication.
16. Purdy, W. C., "Plankton Studies." In: "Investigation of the Pollution and Sanitary Conditions of the Potomac Watershed." Hygienic Laboratory. Treasury Dept. USPHS Bull. No. 104 (1916).
17. Krauss, R. W., "Photosynthesis in the Algae." *Ind. and Eng. Chem.*, **48**, 9, 1449 (1956).
18. Allen, L. A., and Smith, H. M., "New Methods of Enumeration in the Bacteriological Survey of a Polluted Stream." *Proc. Internat. Assn. Theoret. Appl. Limnol.*, Stuttgart, **12**, 690 (1955).
19. Ingram, W. M., and Prescott, G. W., "Illustrations of Fresh Water Algae Toxic to Animals." Pamphlet from Ohio-Tennessee Drainage Basins Office, Division of Water Pollution Control, Federal Security Agency, USPHS, Cincinnati, Ohio (1952).
20. Otterstrom, C. V., and Nielsen, E. S., "Two Cases of Extensive Mortality in Fishes Caused by the Flagellate Prymnesium parvum Carter." *Kept. Danish Biol. Sta.*, **44**, 5 (1939).
21. Lea, W. L., Rohlich, G. A., and Katz, W. J., "Removal of Phosphates from Treated Sewage." THIS JOURNAL, **26**, 3, 261 (Mar. 1954).
22. Foyn, E., "Elektrolytisk Kloakkrensing. Regionplankomiteen for Oslo-omradet." *Foredragshefte* No. 5, Oslo (1956).
23. Singh, R. N., "Limnological Relations of Indian Inland Waters with Special Reference to Waterblooms." *Proc. Internat. Assn. Theoret. Appl. Limnol.*, Stuttgart, **12**, 831 (1955).

USPHS TRAINING COURSES

The Public Health Service's Robert A. Taft Sanitary Engineering Center during the winter season is offering a series of specialized courses covering stream conditions, analytical procedures, radiological health, nuclear energy aspects of sanitary engineering, and radiological significance of water and air pollution. A list of the courses still available are:

Nov. 3–14	Plankton Identification and Control
Nov. 17–21	Radioactive Pollutants in Water
Dec. 1–12	Chemical Analyses for Water Quality
Dec. 1–12	Sanitary Engineering Aspects of Nuclear Energy
Jan. 12–23	Basic Radiological Health
Jan. 26–30	Sanitary Bacteriology of Water
Jan. 26–30	Radioactive Pollutants in Air
Feb. 16–20	Radioactive Pollutants in Water

These courses are available to those interested in the particular programs for which courses are listed. No tuition fee is required. Applications should be addressed to the Chief, Training Program, Robert A. Taft Sanitary Engineering Center, 4676 Columbia Parkway, Cincinnati 26, Ohio, or to the appropriate Public Health Service Regional Director.

CHIRONOMIDS AND LAKE NUTRIENTS IN FLORIDA *

By Maurice W. Provost

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In recent years, Florida has had an increasing problem with "blind mosquitoes" or more specifically, chironomid midges. These non-biting midges, whose larvae are the well-known "bloodworms" of lakes, ponds, and streams, become a nuisance only when overly abundant, because otherwise they are not only harmless as adults but very beneficial as larvae when they are a dietary staple for a large variety of fish—game and otherwise. The same waterfront homeowner may want good fishing, calling for bloodworm production, and freedom from blind mosquitoes, calling for chironomid eradication. What might satisfy these needs would be a chironomid that never leaves the water. This is an impossible demand in Florida, yet there is such a chironomid in Samoa.

To tie this discussion in with pollution problems, it appears that overproduction of chironomids is a product of excessively nutritious waters. The effluent from a sewage treatment plant, rich in inorganic nitrogen and phosphorus, may be refined fertilizer to the waters. This belief received support from the sudden rise of blind-mosquito complaints in the years since 1945 during which the number of sewage treatment plants has increased substantially. Further strength was given this theory when it became well established that sewage plant effluent did promote the growth of phytoplankton (1)(2). Still further confirmation was received by reports from central and northern Europe that over-production of chironomids was a frequent consequence of sewage treatment plant effluent being discharged into lakes. Indeed, some Danish limnologists consider chironomids of the genus *Glyptotendipes* to be indicators of pollution by sewage treatment plant effluent (3). Coincidentally, or otherwise, out of the scores of chironomid genera, the pestiferous blind mosquito most often a problem in Florida is also in the genus *Glyptotendipes*.

Winter Haven Problem

Among the cities in Florida with blind-mosquito problems, none have been more demanding than Winter Haven. From 1928 until 1949, this growing city had been discharging its untreated sewage in one of the "chain-of-lakes," Lake May. In 1949 its new sewage treatment plant went into operation, disposing of its effluent in Lake Lulu, another one of the "chain-of-lakes."

In 1950 people who resided on the lakes asked for control of the blind mosquitoes which were coming out in vast numbers from all the lakes in the chain. In 1951 an entomologist from the State Board of Health spent the summer in Winter Haven investigating the blind-mosquito problem and was able to (a) learn the first basic facts in the biology of the chief offender, *Glyptotendipes paripes*, (b) demonstrate the feasibility of reducing the adult chironomids with DDT applied by thermal aerosol generator, and (c) develop an excellent larval control

* Presented at the Annual Meeting of the Florida Sewage and Industrial Wastes Assn.; Jacksonville, Fla.; Nov. 11–13, 1957.

method using water-wettable BHC applied in the wake of a motorboat.

At this time the city of Winter Haven assumed control. However, in less than two years the larvae developed sufficient tolerance to BHC to make lake treatments ineffective. Results of further studies revealed EPN to be a good larvacide, but this was effective only a year and a half during which the blind-mosquito larvae developed a resistance.

At this time, the control problem was discouraging and considerable pressure was exerted by residents for action. Past experience showed that temporary measures would not suffice. Therefore, a fundamental study was recommended. However, before recommending a research plan and organization, a preliminary or "pilot" investigation was carried on in the summer of 1956.

Survey Procedure

The 1956 survey attempted to establish tentatively the following three points:

1. The chironomid species that breed on the various lake bottoms of the Winter Haven area.
2. The association existing between these various species and the different lake waters and bottoms as environments for the larvae.
3. The association existing between chironomid production and the several disturbances by man's activities of the natural conditions in these lakes.

Thirteen Polk County lakes were selected for study. These were divided among: (a) two undisturbed lakes, with no homes, groves, sewage plants, or industries on their shores, (b) two industrial lakes where the most obvious source of nutrients was canning plants, with few homes and no sewage plant or citrus groves on their shores, (c) two citrus lakes, whose only possible disturbance was the washing-in of fertilizer from citrus groves, (d) two septic-tank lakes where the only possible nutrient source was septic tanks for the homes lining their shores, (e) two sewage-plant lakes, with little other possible source of nutrients than effluent from sewage treatment plants, and finally (f) three of the Winter Haven "Chain-o-lakes" with many possible nutrient sources and all of them well-known producers of *Glyptotendipes paripes*.

Various physical and chemical measurements were made and larvae and plankton samples were collected systematically. Identification and classification were done during the winter season.

Survey Results

From this effort came a preliminary report pointing out that the heaviest blind-mosquito producing lakes were those likely to receive the most inorganic nutrients, provided that the right kind of bottom was present. The report further dealt with (a) the various chironomid species and their distribution as affected by bottom characteristics, (b) the limnology of the lakes with emphasis on plankton production, and (c) the food habits of the major chironomid pest, *Glyptotendipes paripes*. It was shown that this latter species breeds on sand bottoms, irrespective of depth and a large number of other variables (water transparency, pH, alkalinity, etc.); that it feeds on algae to the extent of 99 per cent; that it eats planktonic algae nonselectively; and that the amount of algae in larval stomachs is proportional to the density of planktonic algae in the lake. Since only 259 larval stomachs from only 9 lakes were studied, further data are needed to demonstrate more fully this relationship. However, the belief is partly confirmed that the larvae circulate a fixed amount of water through their nest tubes and nets and, therefore, that the rate of growth varies directly with the plankton density in the water. If this is proved, it will then be definite

that more inorganic nutrients in the water result in more phytoplankton, and more phytoplankton result in more blind mosquitoes. Control of the blind mosquitoes will then become a matter of controlling whatever source of inorganic nutrients might be involved, and it is known that sewage treatment plant effluent is one of them.

Action Taken

On the basis of the pilot study, it was recommended that a research organization be developed to investigate this problem thoroughly. This has been done and the present Midge Investigation Program is pursuing three objectives simultaneously: (a) biological studies of the midges, with special attention to life histories, behavior, food habits, and ecology, (b) limnological studies of 19 selected lakes, with emphasis on relationship of nutrient sources and plankton production, and (c) control studies, aimed at eventual elimination of the problem but with special immediate attention to such control measures as larvaciding and adulticiding.

It is hoped that it will soon be possible to speak more intelligently on the production of blind mosquitoes in Florida and especially on the role therein of effluents from sewage treatment plants.

References

1. Hasler, A. D., "Eutrophication of Lakes by Domestic Drainage." *Ecology*, **28**, 4, 383 (1947).
2. Sawyer, C. W., "Fertilization of Lakes by Agricultural and Urban Drainage." *Jour. New Engl. Water Works Assoc.*, **61**, 109 (1947).
3. Kaiser, E. W., "Mølleåen 1946 og 1947." *Dansk Ingeniørforening, Spildvandskomitéen* (Denmark), **1**, 19 (1949).

INCREASED FELLOWSHIP STIPENDS

An increase in stipend rates for research fellowships has been announced by two Federal agencies, the National Science Foundation and the Public Health Service.

The increased stipends, now available for future fellowships, put into effect the recommendations of senior scientists in training centers throughout the Nation. A survey of these scientists supported this increase as necessary to sustain the productive research training programs of the two Federal agencies in non-Federal, non-profit research institutions.

The stipends from both agencies at the predoctoral level will be increased by $200. The new amount will be $1,800 for the first year, $2,000 for the intermediate year, and $2,200 for the terminal year. Predoctoral allowances have been increased to permit $500 for each dependent.

The new stipends for both agencies at the postdoctoral level will be $4,500 for the first year and $5,000 for the second year. In addition, postdoctoral allowances have been increased to provide $500 for each dependent.

Other allowances for certain travel expenses and research supplies will remain unchanged for both predoctoral and postdoctoral levels.

National Science Foundation fellowships are awarded in all fields of science, while Public Health Service research fellowships are awarded in health, medical, and related sciences.

THE OPERATOR'S CORNER

CLEANING THE CONEY ISLAND OUTFALL SEWER*

By Arthur J. Scanlon

Chief, Bureau of Sewage Disposal Operation, New York, N. Y.

The Coney Island Pollution Control Project, located in the Sheepshead Bay area of the Borough of Brooklyn, New York, N. Y., is a primary treatment plant of 70 mgd capacity. Because of its proximity to bathing beaches, the plant was designed for chemical treatment and chlorination during the bathing season. This plant, the first of the modern sewage treatment plants in New York City, has been in operation since 1935. In 1941 the plant capacity was increased from 35 mgd to its present size.

The outfall sewer, built in 1934, was designed to take care of future plant enlargement. However, shortly after World War II it was found to be below its design capacity. In the process of solving this problem, the Coney Island outfall sewer became the largest diameter pipe ever cleaned with a cleaning machine.

Once an outfall sewer is constructed it is out of sight and, unfortunately, all too often forgotten. This is not due to any lack of interest on the part of the plant operators but rather to the fact that most outfall sewers are built without access manholes for visual inspection. This method of construction is true of the Coney Island outfall sewer, which is 8,500 ft long and 72 in. in diameter. Approximately 80 per cent of the outfall sewer is under water, terminating in an outlet chamber with diffusers, in some 20 ft of water, in the Rockaway Inlet. There are only two small openings in the full length of the outfall sewer, a 2-in. air vent at Sta. 2 + 80 and a 6-in. vent at Sta. 17 + 80. The only other access is through the plant effluent channel. Because of its steep drop and bends the channel is considered unsafe for entry.

Loss of Capacity

Near the end of 1946, hydraulic tests showed the actual capacity was somewhat lower than the design capacity. One possible explanation was that the diffusers were clogged. Subsequent determination of the diffuser head loss indicated the diffusers were not responsible.

Another explanation attributed reduced carrying capacity to air-binding. When low flows occur during low-tide conditions approximately 1,800 ft of the pipe under the land is only two-thirds full. When the flow increases or the tide rises, the air pocket, thus formed, is relieved through the two vents. Hydraulic tests with the air relief valves closed showed additional loss of carry-

* Presented at the Spring Meeting, New York Sewage and Industrial Wastes Assn.; Liberty, N. Y.; May 26–28, 1958.

ing capacity. In 1948 larger air relief vents were installed. Tests made after their installation showed the major reduction in carrying capacity could not be blamed entirely on air-binding, although some additional head loss is present in the complete absence of venting.

Pollutional Aspects

Before the start of the 1949 bathing season, the reduced carrying capacity of the outfall sewer coupled with the increased flow to the plant presented the Bureau of Sewage Disposal Operation with the possibility that unchlorinated final effluent, at times of high tide and high flow, might be diverted to Shellbank Creek. The discharge of unchlorinated effluent to Shellbank Creek was totally undesirable, not only because of the recreational activities along the creek, but also because the discharge of any pollutional load into the land-locked creek would in turn pollute the waters of land-locked Jamaica Bay and create a health problem. To preclude the possibility of such an occurrence, chlorination of the raw sewage was initiated soon after the start of the 1949 bathing season. The increased cost of pre-chlorination was an added factor in the search for a method of restoring the capacity of the outfall sewer.

Inspection of Outfall

Additional hydraulic tests showed that the Hazen-Williams coefficient of the land section was about the same as for the section under water. Since the likelihood of any major obstruction in the outfall sewer was remote, further reasoning pointed to the possibility that the drop in carrying capacity might be due to slime growths.

Near the end of 1949, an inspection of the walls of the outfall sewer was decided upon. As mentioned before, provisions to gain access to the interior of the sewer were lacking. An ingenious method was hit upon. The inspection was made by means of a mirror and light arrangement through the 6-in. vent pipe connected to the air relief valve at Sta. 17 + 80. This gadget was immediately dubbed a "proctoscope." It was estimated that the thickness of the slime was about ¼ in. Some of the slime was scraped off the pipe and recovered. It had no odor when fresh but quickly developed an odor of hydrogen sulfide. The slime was definitely analyzed as a biological growth and not grease. It must be kept in mind that the inspection was made through a 6-in. pipe and that a more complete inspection would have been desirable. However, the only other possibility was through the effluent channel and this was too hazardous to venture.

Search for a Solution

Chemical Methods

Since the inspection indicated the loss of capacity might be due to a biological slime, the problem now was to loosen it. In an attempt to dislodge the slime, chlorine was applied to the plant effluent in such dosage as to yield a residual of between 15 and 20 ppm. An inspection of the pipe interior using the "proctoscope," after completion of the high chlorine dosage for a 10-day period, showed no change in the slime growth and hydraulic tests of the outfall sewer showed no improvement in carrying capacity. Further efforts to dislodge the slime using copper sulfate in concentrations of 30 to 40 ppm also failed.

Mechanical Methods

During the 1950 bathing season, chlorination of the raw sewage was again resorted to. Meanwhile, investigations were started on the use of a mechanical method for removing the slime growth. There were misgivings concerning the use of a cleaning ma-

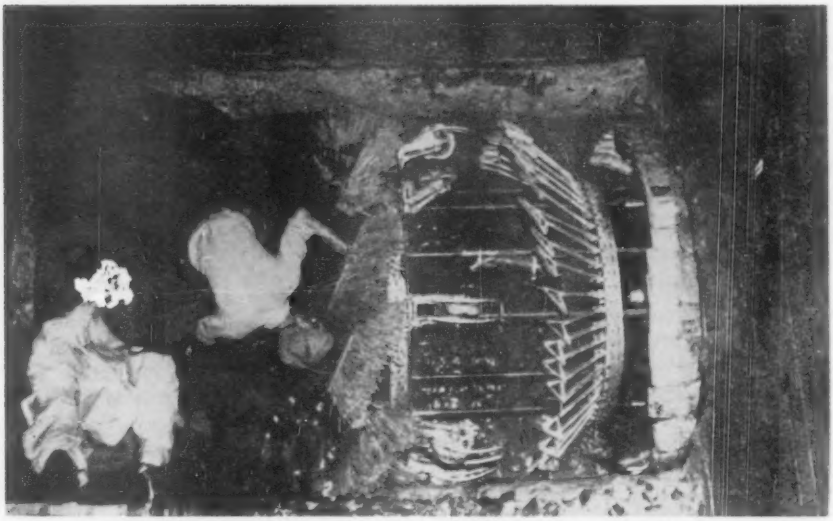

FIGURE 1.—Cleaning tool being jacked into 72-in. outfall sewer.

chine. However, the cost of such a cleaning operation was attractive when compared with the other two alternates: (a) the continued cost of prechlorination and the discharge of pollutional load into Shellbank Creek, or (b) the building of a new outfall.

In the early part of 1951, two contracts were initiated for the cleaning operation of the outfall sewer. One contract covered the construction of an access manhole on the 72-in. outfall sewer, the cutting of an opening in the roof of the outfall chamber, and the furnishing of the necessary equipment and personnel for lowering and removing the sewer cleaning machine. The second contract covered the supplying of a cleaning machine, auxiliary equipment, and technical advice on the passage of the machine through the outfall sewer. The payment on the second contract was based on the improvement of the Hazen-Williams coefficient. Full payment was to be made for a coefficient of 135 and no payment for a coefficient of 110. A coefficient between 110 to 135 was to be paid for at the rate of $400 per point above 110. Further, the contractor agreed to future rental of the cleaning machine for the next ten years if and when required.

During June 1951, before the first cleaning operation was undertaken, the Hazen-Williams coefficient was determined to be 99.

On June 29, 1951, the first cleaning operation was carried out. An inspection of the outfall sewer for some 150 ft from the access manhole was made prior to the cleaning operation. The surface of the 72-in. sewer was covered with about ¾ in. of slime. Since there was about 2 ft of water in the bottom portion of the section inspected, a complete inspection could not be made. However, debris also covered with slime was found on the bottom and removed to the surface. The slime was easily scraped from the surface of the sewer. The surface of the slime was greyish white with ripples at varying distances along the length of the outfall. Under the surface the slime was black.

After the inspection, the cleaning machine or "go-devil," as it was

called, was lowered into the access manhole. During the lowering sewage was diverted to Shellbank Creek. Within an hour fishermen visited the plant to inquire about the sewage entering the creek. On all subsequent cleaning operations sewage was stored in the wet well and trunk sewers when the go-devil was being lowered or removed.

Cleaning Tool

The go-devil (Figure 1) is 8 ft 6 in. long and consists of four steel rings, slightly smaller than the diameter of the pipe, which are held together by rods and spacers. On the first and third rings, wheels are mounted to fit snugly into the pipe. Mounted on the front ring is an adjustable conical closure so designed that the amount of water passing the machine may be predetermined; thus the driving force may be controlled. A continuous series of spring-like fins is also attached to the back of the front ring to form a seal against the inside of the pipe. The combination of cone and fins is known as the driving head or piston. Spring-mounted street cleaning brushes are attached to the second ring and spring-mounted rubber squeeges to the fourth ring.

Precautions Taken

The cleaning operation was not without risk and extensive plans were made to locate the go-devil in case of stoppage. Transit control stations were established on shore so that any stoppage could be located by triangulation. A launch, provided with detection equipment, was to follow the path of the go-devil and pick up signals from an oscillator installed on the cleaning machine. To tie-in all operations, personnel on the launch, at the plant, at the control stations on land, and at the outfall chamber were provided with walkie-talkies. In the event of a stoppage, the launch was to center over the go-devil and the control stations would fix its location. Two days prior to the cleaning operation, a dry run was carried out so that all personnel involved in the operation would be familiar with the equipment and the procedure.

After the go-devil was jacked into place, the plant flow was turned back into the sewer and the go-devil was on its way to the outfall chamber. But, alas, to quote the famous Scotch poet Robert Burns: "The best laid schemes of mice and men gang aft a-gley," and so it was that no sooner than the go-devil was on its way, a sudden thunderstorm, accompanied by a deluge of rain, turned the actual run into a very wet-run indeed, resulting in difficulties in visibility and communication.

However, observers at the outfall chamber reported that about an hour and a half after the start of the go-devil from the access manhole, black specks appeared in the effluent followed by some ten minutes of very black effluent. Grappling hooks showed that the go-devil was at the outfall chamber. The flow was turned off, the diver entered the outfall chamber and the go-devil was raised to the surface.

Results

On July 5, 1951, hydraulic measurements showed that the Hazen-Williams coefficient of the outfall sewer was 130.

A second pass of the cleaning tool took place on July 10. This time, when the sewage was turned back to the outfall sewer and the go-devil started to move, a heavy dosage of chlorine was added for bactericidal purposes.

On July 11, as a result of the cleaning, orders were given to stop pre-chlorination and begin post-chlorination since it was now established that spillover to Shellbank Creek was no longer possible at high tides. A third pass took place on July 27, and final hy-

draulic measurements showed the Hazen-Williams coefficient to be 136.

Thus the 72-in. outfall sewer of the Coney Island plant was returned to approximately its design capacity. While there was great satisfaction with the results obtained on the completion of the first cleaning contract, it was predicted that the slime growths would return. At regular intervals, hydraulic measurements have been made as a check on the slime growths. The variation of the Hazen-Williams coefficient since 1951 is shown in Figure 2.

After completion of the first cleaning contract there was a rather sharp drop in the coefficient, followed by a gradual decrease. A coefficient of 110 is required to carry a flow of 90 mgd at critical tide conditions. As the critical coefficient is approached, cleaning operations must be considered. In the spring of 1953, the second cleaning operation was carried out. Two passes of the go-devil were made and again the coefficient was restored to a high value. The loss of carrying capacity following the second cleaning was similar to the pattern that obtained after the first cleaning. Again in 1954, the coefficient approached the critical range and a third cleaning was carried out with but one pass of the go-devil. In the early part of 1955, another try was made in the use of chlorine in high dosages to arrest the growth of slime. While there was a slight improvement the chlorine had no appreciable effect on arresting the regrowth of slime (Figure 2).

In 1955 a fourth cleaning was undertaken. It was decided to revert to the practice of the first cleaning operation, when three passes of the go-devil were made, in order to determine the economic advantage of the additional passes. At the conclusion of the fourth cleaning operation, great interest and concern were felt over the resulting high coefficient of 160. The possibility existed that the outfall sewer had ruptured and that all the flow was not going to the outfall chamber. Frequent dye tests were made to determine whether a break existed in the outfall sewer. No breaks were found. A possible explanation for the high coefficient is that the three passes of the go-devil developed a surface which is hydraulically smoother than a concrete surface. At any rate, the high coefficient did not last long and the pattern of a rather sharp drop followed by a gradual decrease again obtained. However, no more cleaning operations have taken place and hy-

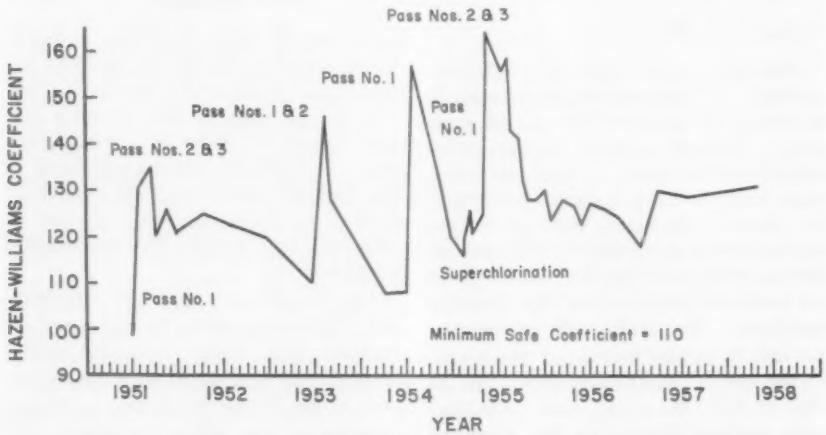

FIGURE 2.—Hazen-Williams coefficient of Coney Island outfall sewer.

draulic measurements in April, 1958 showed the coefficient to be 134. No cleaning operations are planned for the year 1958 and the indications are that the cleaning of 1955, using three passes of the go-devil, will last at least three years and possibly four.

Summary

For the past seven years, the hydraulic capacity of the 72-in. outfall sewer at the Coney Island plant has been maintained by the use of a cleaning machine. The average daily flow to the plant for the year 1957 was 71.8 mgd, slightly above the design capacity of 70 mgd. At no time since the first cleaning operation in 1951 has any bypassing to Shellbank Creek occurred. Since the first cleaning operation in 1951, chlorination of the plant effluent has been carried out at a material saving compared with the chlorination of raw sewage carried out in 1949, 1950, and part of 1951. While the reduced chlorine consumption is a direct monetary saving, the prevention of the discharge of a pollutional load into the waters of Jamaica Bay throughout the entire year must also be considered an asset.

The cost of all cleaning operations amounted to about $38,000. The biggest item in the total was $17,000 for the modification of the outfall sewer and outfall chamber. The second, third, and fourth cleaning operations averaged about $3,500 each, including the cost of the use of the cleaning machine. Against this is the saving in the cost of chlorine over the past seven years. Comparing the consumption for the years 1950 and 1952, when pre- and post-chlorination were used, the saving averaged a ton of chlorine a day. At a cost of $100 a ton the saving in chlorine totals approximately $100,000 for the past seven years, or a saving of some $62,000 over the cost of all the cleaning operations to date.

Conclusions

Several observations made during the course of the work are mentioned in the hope they may be of some value to designers as well as operators.

Access manholes should be provided so that inspections of the outfall sewer can be made. Slime growths and perhaps other growths will form on outfall sewers. A series of articles by Heukelekian and Crosby (1)(2)(3) describe the growth of biological slimes on various surfaces in contact with sewage. They indicate that such growths will occur, even where inhibiting agents are incorporated with the concrete, and that the growths will increase in thickness, then slough off, with regrowth following. These findings were confirmed by the Coney Island experiences wherein it was found an equilibrium is reached at a Hazen-Williams coefficient of about 100. The question has often been asked whether an outfall sewer should be designed using a coefficient of 100. Before answering this question, one must weigh the relative cost of a larger diameter pipe against the cost of providing access manholes and provisions for the use of a cleaning machine. Experience with the Coney Island outfall sewer gives the answer: Provide access manholes so that outfall sewers can be cleaned of biological slimes. This is both practical and more economical than over-designing the outfall sewer to take care of reduced capacity caused by slime growths.

References

1. Heukelekian, H., and Crosby, E. S., "Protective Coatings and Slime Growths." THIS JOURNAL, **25**, 8, 869 (Aug. 1953).
2. Heukelekian, H., and Crosby, E. S., "Slime Formation in Polluted Waters." THIS JOURNAL, **27**, 12, 1391 (Dec. 1955).
3. Heukelekian, H., and Crosby, E. S., "Slime Formation in Polluted Waters." THIS JOURNAL, **28**, 1, 78 (Jan. 1956).

WORLD'S DEEPEST SUBMARINE PIPELINE *

By David R. Miller

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A key feature of the $47,000,000 Hyperion sewerage expansion program of the City of Los Angeles—the $2,500,000 Hyperion ocean outfall for sludge discharge—will permit disposal of digested sludge from the Hyperion sewage treatment plant through a submarine pipeline into Santa Monica Bay. The seven-mile outfall was installed in seven and a half days. It is the deepest submarine pipeline ever constructed by virtue of its termination depth of 312 ft, and its 7-mile subaqueous length makes it the longest sewer outfall in the world. In addition, the contractor, by electing to install the line by the pulling method, broke the pulling record of 20,000 ft set in 1953 at the Straits of Mackinac.

In view of the unprecedented nature of the proposed project extensive research into the various problems involved was carried out. Installations in the United States where sludge pumping has been practiced on a large scale were checked and selected subaqueous installations on both coasts were visited. The experience of the oil and gas industry in constructing off-shore loading and gathering lines was also investigated. In addition, special studies were carried out to determine the ability of Santa Monica Bay to receive the average flow of 2.45 mgd of digested sludge. An oceanographic research program under the direction of the Allan Hancock Foundation of the University of Southern California yielded much in the way of design information concerning the current and temperature patterns in the Bay and also data on the behavior of digested sludge.

In order to ascertain the bottom conditions in the vicinity of the pipeline, engineers and geologists with skin-diving equipment checked the line with water jet probes out to a depth of 150 ft. In the near-shore region where the pipe was to be buried, a portable drilling tower was set up and undisturbed samples were taken at several stations. The portion of the line seaward of 150-ft depth was tested by punching weighted tubes into the bottom from the survey ship. Bottom sediment samples were obtained with a snapper.

In order to minimize clogging and sediment build-up in the pipe, a flow of 5.5 mgd will always be maintained. This is accomplished automatically by adding plant effluent to the flow of digested sludge so that the total quantity will be constant. The existing sludge pumping plant was modified to incorporate two 8-in. centrifugal pumps, each of which will deliver 3,000 gpm at a head of 50 ft.

The outfall line is a 22-in. OD steel pipe manufactured in 40-ft lengths by the expanding process. The specifications called for A.P.I. 5-LX pipe with a minimum yield strength of 52,000 psi. The actual yield strength observed in tests ranged up to 67,000 psi. For corrosion protection, the line has a triple wrapped coating of coal tar enamel,† reinforced with two layers of fiber glass with a 1⅛-in. outer coat of reinforced gunite; a ½-in. centrifugally spun cement mortar lining protects the interior of the pipe.

In order to provide additional protection to the steel pipeline, a cathodic protection system was incorporated into the project. With an ample supply of low-cost power available at the

* Presented at the 1958 Annual Meeting, California Sewage and Industrial Wastes Assn.; Stockton, Calif.; April 23–26, 1958.

† Koppers 70-B.

nearby Hyperion plant, the rectifier system of cathodic protection was chosen, not only for the protection afforded the line, but also because with proper testing facilities it is possible to continuously monitor the condition of the coating during installation. An excellent coating job was achieved and because of this current requirements have been found to be less than 0.5 amp.

The construction and installation of this project have been likened to a modern military invasion operation since it made such extensive use of helicopters, radio, underwater television, divers, and new and unusual construction techniques.

TRAINING FOR SEWAGE TREATMENT PLANT OPERATORS *

By W. A. Hardenbergh

Editor, Public Works Magazine, Ridgewood, N. J.

A modern sewage treatment plant represents a large investment in money, but it has no second-hand value. It can be used for no other purpose than the one for which it was designed. The money spent for its construction can never be recovered except through many years of good service.

The facts emphasize the need for good operation; and good operation does not come easily. A sound training program through which all operators can benefit is the first essential. Beyond that and vital to its success are the methods through which the training is made available to operators, the reactions of the communities which employ the operators, and, perhaps most important of all, the attitudes of the operators themselves.

Basically, of course, the sewage treatment plant has always been behind the 8-ball as compared to the water department, which makes money and is generally considered as the preserve of sound and prosperous business men. The sewage treatment plant, on the other hand, has no earning ability and does not create income. It takes good management, technical knowledge, and some selling ability to operate satisfactorily under this handicap. The operator working alone finds it difficult to overcome the problems so often inherent in his position.

A training program therefore must, in itself or preferably in combination with a broader campaign of public education, provide the operator with the knowledge he needs to get the most out of his plant; and it must also educate public officials to the importance of and the need for skillful treatment plant operation.

It is believed that most operator training programs are not adequate. In fact, it has seemed that in too many cases no one is really responsible for an effective training program. In view of the great basic importance of proper waste treatment—the prevention of stream pollution and the conservation of water resources—it is time to take a new look at the problem. There is another reason for this right now. The Federal Government two years ago initiated a system of grants to aid in sewage treatment plant construction. It is only common sense to conclude that, if the plants built under this program are inadequately operated (therefore nullifying any values con-

* Presented at the Annual Meeting, New York Sewage and Industrial Wastes Association; New York, N. Y.; Jan. 23, 1958.

tributed), the program will not long endure.

Team Work in Training

It takes more than sanitary engineering knowledge to develop a training program. Techniques in education are as important as techniques in engineering and the educational agencies of the state should cooperate with the health agencies to develop a training system. Thereafter application should be primarily a responsibility of the educational agency, working closely with the health department. Each is necessary and each can contribute essential elements to the program.

Training Text

A complete training program could and should include many things not now available, except in perhaps a few states. The first essential is the preparation of a comprehensive training text. No such text is now available though useful basic material of considerable length was published a few months ago. Preparation of the comprehensive text should be the joint responsibility of the health and educational agencies. Then the entire program of training should be coordinated to permit progressive training from the elementary phases of operation to the most advanced.

Types of Training

Training should be available to all and in a variety of forms, including sectional meetings, short schools, special college courses, and correspondence courses. A program of this nature will require qualified instructors, the use of extension school facilities, and a careful coordination of all these methods of instruction to provide a fully rounded and complete course. In carrying it out, reasonable consideration must be given to the convenience of the operators, avoiding encroachment on their leisure time, burdensome costs, and the necessity for frequent long trips to attend classes.

Local Support

No program can be fully successful unless it has the approval and the cooperation of the civilian heads of the communities that employ operators. Understandably, it will be difficult for an operator to take advantage of the training program unless his local officials understand the benefits to be derived from such training. Therefore, an intensive campaign to obtain the understanding, the interest, and the support of local officials for operator training will be necessary. This can best be done through existing governmental public relations departments—those of the state in general, of the health department, and of available local public and private agencies. Team work between health and public relations agencies will permit assembling necessary public health data on which to base the campaign; and will assure that time-proved methods of public relations are employed over a sufficiently long period.

The necessity for a comprehensive approach is illustrated by considering the problems of reaching the many sewer districts in this State. As of 1952, there were more than 150 such districts in New York; in one county of about 40,000 population there are at least eleven districts with sewage treatment plants costing in the aggregate probably in excess of a million and a half dollars. These sewer districts are under direction of a town board and the operators have no technical personnel to whom they can go for advice or assistance; nor do they have, as a rule, any understanding channels through which to submit recommendations. A training and public relations program must reach these town officials in order to provide maximum benefits for the small plant operators. It would probably be bene-

ficial to have these districts placed by law under the technical supervision of the county engineer, where there is one; or where there is no county engineer, to permit or require employment of a consulting engineer to supervise operations under a standard contract form designed to meet sewer district needs and to protect the considerable investment in treatment plants.

New York, of course, is not alone in this problem. Metropolitan Denver contains 45 sewer districts or generally similar units with 34 sewage treatment plants. Harris County, Tex., has 97 sewage treatment plants. These figures indicates the importance of the small plants on the bases of population served, investment in plant, and potentialities in pollution.

Role of Consulting Engineers

Consulting engineers can be helpful in the training program and a fuller use of their facilities could result in improved operation. There are several ways by which this can be attained. When constructing a new plant, early selection of an operator by the community and his employment in a suitable capacity during construction will permit acquisition of knowledge invaluable in later operation. If a plant already exists, the community should be urged to send the operator to training courses and, in addition, he should spend at least one day a week at the new plant during construction. He should be well briefed on each plant unit, its construction and how it works, and he should have and study plant plans. During the period of design and construction, consultants can confer with and educate local officials on the need for good operator training. Supervision of operation for a stated period after completion of the plant is also desirable.

All of these things are needed so that the operator is picked carefully, is qualified initially, and is given the opportunity to improve his knowledge through a carefully planned and administered training program.

What the Operator Can Do

The state, acting through its various agencies, can provide the mechanics for a training program, but in the final analysis its success will depend upon the operator. He can do more to help himself than can all others combined.

Present day needs and standards require training which, in turn, requires a willingness to study and progress. Our waste treatment plants are becoming increasingly complicated and technical, and good operation demands at least a surface knowledge of some elements in electrical, chemical, mechanical, and sanitary engineering and perhaps a little of bacteriology; and, in addition, a lot of good common sense. The service derived from a sewage treatment plant depends more on the quality of operation than on any other factor.

Plant Operation

The obligations imposed on the operator of a sewage treatment plant require, first of all, a background of good citizenship. He represents his community in his every-day work. Careless operation of the plant can cause disease or create nuisances affecting not only those living near the plant but others many miles downstream. And such careless operation can involve his community in serious damage suits. Thus, consistently good operating results are a necessity from day to day; but, in addition, the operator must look forward to a continuation of these results. That means study of the need for repairs, for new equipment, for enlargement, and for any other work necessary to keep the plant in first-class condition. The responsible officials must be kept informed of these needs so they will have the necessary time to supply

them. The operator should also know when his plant is beginning to reach its limits of effective service so that local officials will have plenty of time to act. It takes a minimum of two years and up to eight or ten years to get a sewage treatment plant authorized, designed, and built.

From time to time there will be unusual problems—filter clogging, bad odors, upset digesters, or a new or stronger variety of industrial waste. The operator must be able, with rare exceptions, to handle these problems—not always alone, but with help. Next to knowing the answer himself, it is best to know someone who has the solution. Through training and attendance at short courses, the operator gets a double benefit. He learns much himself; and he meets and gets acquainted with others who have the same problems that he has and on whom he often can call for advice and help.

The generally poor pay for operators stems from a variety of causes. Better training can help, but there are many things an operator can do which will benefit his community and also himself. Here are some of the things he can do.

Sewage Flow

It costs money to treat excessive volumes of sewage, and there are other objections, also, to excessive storm flows. For instance, if a new plant is to be built, it will be disastrous to design it for too small a flow, and it may be very costly to make it large enough to handle wet weather flows. The operator should note the relationships between rains and sewage flow and the duration of the heavy flow. Also, he should note normal flows and hourly and daily variations. He should be sure that his flow meter is correct. It is well to check the meter from time to time by the methods he will learn in his training program. He may even attempt to locate the more serious points of infiltration.

The data he obtains should be carefully checked and recorded and copies sent, with an explanatory note, to the city engineer or other proper authority.

Industrial Wastes

In many cities there are industrial plants that produce wastes that must be treated. Where these are discharged into the sewers and are treated at the plant, note should be made of their effect, if any, on plant operation. It is well to get samples and records of discharge by strength and volume from the industries contributing wastes to the sewers. If these wastes cause trouble, a schedule may be worked out for discharging them uniformly over a 24-hr period. The operator should know what wastes are reaching his plant and what their characteristics are. He may try some laboratory experimentation on some of the wastes, with the approval of the city officials. Perhaps, also, he may find some industries discharging wastes which ought to and could be treated in his plant, thus bringing in some additional income to the city.

Additional Equipment

Almost every sewage treatment plant is a compromise between what is wanted and the amount of money available. That means that often some quite essential units were omitted when the plant was built. The operator can detect these lacks and often can get them supplied. These needs include such things as comminutors, which eliminate the disagreeable task and tiresome labor of cleaning screens and burying or burning the screenings; grit removal equipment which may eliminate grit troubles in the primary settling tanks and in the digesters; adequate laboratory equipment and laboratory space; a shower bath, toilet, and clothes storage space; a work

bench and storage space for tools; a portable centrifugal pump; and modern type office furniture and equipment.

Forecast Needs

The operator is in perhaps the best position of anyone to analyze the real needs of the community for sewage treatment, bearing in mind such things as rate of population growth; volume and strength of sewage; industrial additions; capacity of the receiving stream; and degree of treatment needed. Knowing these factors, his advice and help can be of very great value to the community in providing the data on which to base future planning. Observation of these factors and their preservation in the form of records can help the community to meet its future needs in the most economical and advantageous fashion.

Cost Analysis

The cost of operation of a sewage treatment plant is often a sore point among budget makers. For this reason, a cost analysis of plant operations is very desirable. The operator should know what each step in treatment costs—within reasonable limits—and should also know whether or not this cost is about what it should be. He should know if he can get as good or better results at a lower cost by some other method. For instance, what does it cost in man-hours and truck-hours to clean a sludge drying bed? Would it cost less or more to dewater the sludge on a filter? If such a filter were used could plant personnel be reduced? Is 24-hr operation essential; or would a few automatic controls permit 8- or 16-hr operation with considerable saving in labor costs?

Housekeeping

The plant should be kept attractive in appearance and this is really an essential step in any program. The inside should be clean and neat and should look like a modern business office. The laboratory should look enough like a laboratory so if a doctor or a dentist or a skilled laboratory man visits there, he will feel at home, and will go away with an increased respect for what is being done. Files are necessary for record-keeping. Technical books, magazines, and appropriate catalogs are needed to keep in touch with the job—and they look impressive to visitors, too.

Conclusion

The operator should never get so engrossed in the daily routine that he forgets these opportunities, and many others that have not been mentioned but that will occur to a well-trained man. One of the most important jobs is to keep the community familiar with the values the sewage treatment plant can and does render, and with its needs. If, instead, the operator waits for the people of the community to come to him, they will come—bringing troubles, problems, and complaints, but few bouquets and no loose money for needed improvements. The operator's job is no different from many others—it is precisely what he makes it. It can be a fine job, interesting and rewarding in public service; or it can be the reverse—a pain in the neck. Leadership should come from the state, and help, too; but the extra study, the new ideas, and the energy and ability required to translate the potential into reality must come from the operator.

The operator of a sewage treatment plant has a highly responsible job and he ought to know as much about his business as others in the community know about theirs. To accomplish this, better training facilities are essential; but in the final analysis what the individual operator does will pretty much determine what kind of a job he has and how far and how fast he will progress.

INTERESTING EXTRACTS FROM OPERATION REPORTS

"The throwing out of balance of the resources of nature throws out of balance also the lives of men."—F. D. R.

Attention operators! It will be appreciated if copies of the annual reports of both large and small sewage and industrial waste treatment plants are sent to the Federation office for abstracting in this section of the Journal. Please direct annual reports to: The Operator's Corner, SEWAGE AND INDUSTRIAL WASTES, 4435 Wisconsin Ave., N.W., Washington 16, D. C.

Annual Report of the Jackson, Mich., Sewage Treatment Plant for the Fiscal Years 1956 and 1957 *

R. A. GREENE, *Superintendent*

The last of the revenue bonds issued to finance the Jackson, Mich., sewage treatment plant matured on September 1, 1956. These bonds originally totaled $644,000 and were issued in 1936. This amount represented the city's share of the original plant cost. The Federal Government, through a PWA grant, paid 30 per cent of the cost.

Plant Operation

Jackson is served by a combined sewer system and flow to the plant was at an all-time high. A record 3,990 mil gal was treated in 1955–56 and 3,781 mil gal was treated in 1956–57. The increase in flow during the past several years is the result of increased domestic and industrial water usage, particularly the latter. The record flow was partly influenced by a wetter than normal year.

During 1955–56 the power circuit serving the treatment plant was changed by the power company to reduce the load. There were 10 power interruptions in 10 months. Outage times ranged from a few minutes to 45 min. Arrangements were made to restore the old circuit for stand-by service. Even with this arrangement, power outages were of considerable annoyance.

These difficulties cost slightly over $2,000 and many man-hours of extra work. It was necessary to recalibrate the Venturi meters. There also was the danger of the aeration tank diffuser plates clogging when the blowers were idle. During the 1956–57 period only five power interruptions were encountered. Four were of momentary duration and one, caused by storm damage, lasted 2 hr and 45 min.

At times during the past two to three years the peak dry weather flow reached a maximum rate of 14 mgd. This load severely taxed the capacity of the settled sewage pumps. Purchase of a 12-mgd pump to replace a 5-mgd unit now makes it possible to easily handle the dry weather flow.

The plant was designed to permit partial treatment of a large volume of storm flow, above which the excess would be diverted from the combined sewers to Grand River. However, only a small amount of storm flow can be so treated, because Grand River rises quickly and reaches a stage above the elevation of the effluent weir of the primary sedimentation tanks. Under these conditions only that portion of the storm flow that can be given complete treatment can be treated.

The new settled sewage pump will

* For last previous extract see THIS JOURNAL, **29**, 2, 228 (Feb. 1957).

permit flows of 19 mgd to be treated. Although the design capacity of the secondary units is only 11.25 mgd, high flows can be effectively treated since the sewage is relatively weak and contains large quantities of industrial process water.

Treatment efficiencies have averaged 93 per cent for suspended solids removal and 95 per cent for BOD removal. The final effluent averages 13 ppm suspended solids and 6 ppm BOD.

Industrial Wastes

The industrial wastes program has settled into more or less of a routine in which the collection system is sampled and offending industries are notified that their waste discharge is not in accord with the ordinances. Most industries are very cooperative when reminded of their infractions. However, the problem requires constant surveillance.

Oily wastes and wastes from metal finishing plants are the principal industrial materials entering the sewer system in concentrations greater than those permitted by the sewer ordinance. Chromium waste is the most common offender. Analysis is made daily for the presence of chromium in the treated sewage and regular checks are made on the river downstream from the plant. Plant upsets caused by industrial wastes have been virtually eliminated since the initiation of an educational program a few years ago.

Equipment

The need to replace the comminutors has been apparent for several years. Incomplete shredding has caused frequent stoppage of the centrifugal primary sludge pumps. The grit chambers do not produce a satisfactory grit and are incapable of keeping the grit out of the primary clarifiers during peak flows.

Extensive repairs were made to the concrete superstructure of the aeration tanks, primary clarifiers, and digesters. New plug valves were installed on the primary clarifier sludge withdrawal lines in 1956–57. All treatment units operated continuously and in a satisfactory manner during the two-year period (1955–57).

Sludge Digestion

Normally the six sludge digesters are operated as two three-stage units. Total gas production increased slightly and was sufficient to provide for all heating requirements.

Both first-stage digesters were dewatered in 1955–56 and accumulations of sand and scum were removed. Sufficient sand deposits in these digesters to embed the lower heating coils and make efficient heating impossible after three or four years of operation.

Sludge bed cleaning is done by inmates of the state prison. Sludge is used on the prison farms, an arrangement that has worked satisfactorily for 15 years.

Sewer System Maintenance

During fiscal 1956–57 extensive trunk sewer cleaning was undertaken at a cost of $64,000, twice as much as for the routine maintenance program of previous years. The Department of Public Works normally does all sewer cleaning by force account with their own equipment. The increased cleaning program required part of the work to be done by contract. The worst sections of the low-level trunk sewer and interceptor were cleaned.

Increased emphasis on sewer cleaning is part of the program to prevent unnecessary sewage diversion to the river. Sewers partially filled with street washings result in storm water diversion, even at low flows. The diversion chambers have required considerable attention, especially after storms.

Considerable maintenance was required at the three sewage pumping stations. Station operation is automatic, requiring only weekly inspection, pumping down, and cleaning. After more than 100 window panes were broken (vandalism), hardware cloth was installed over them.

Plant Maintenance

The program of preventive maintenance has paid good dividends during the past 20 years. Treatment units have continued in uninterrupted service.

The Jackson, Mich., sewage treatment plant is justly proud of the 35-acre park developed on the plant grounds. New tables continually replace the old, and outdoor grills are provided. Citizens of the community are attracted in large numbers for picnics and other recreation along the river bank. Although maintaining the grounds requires extra work, the beauty and cleanliness of the area have done much to create good will for the treatment plant and the city.

Future Plans

The retirement of the original bonds saw the end of an era and the start of another one. A survey by the Michigan Water Resources Commission in

TABLE I.—Summary of Operation Data for the Jackson, Mich., Sewage Treatment Plant for the Two-Year Period Ending June 30, 1957

Item	Average 1955–56	1956–57
Connected population (est.)	53 000	53,000
Rainfall, total (in.)	35.57	21.76
Sewage treated:		
Mil gal	3,990	3,781
Mgd	10.9	10.4
Gpcd	221	207
Grit (cu ft/mg)	0.66	1.13
Suspended solids:		
Raw (ppm)	183	180
Settled (ppm)	157	153
Final (ppm)	14	12
Reduction (%)	92	93
BOD:		
Raw (ppm)	116	115
Settled (ppm)	93	92
Final (ppm)	16	6
Reduction (%)	95	95
Lb per capita per day, raw	0.21	0.20
Dissolved oxygen (ppm):		
Raw	3.7	3.9
Settled	4.2	4.1
Final	5.6	5.2
Oxygen consumed (ppm):		
Raw	47.7	45.6
Settled	40.9	39.0
Final	10.1	9.2
Organic nitrogen (ppm):		
Raw	7.2	6.8
Settled	6.8	6.4
Final	2.9	2.8
Ammonia nitrogen (ppm):		
Raw	8.7	10.2
Settled	9.3	10.5
Final	9.3	10.5
Nitrite-nitrate nitrogen, final (ppm)	0.0	0.0

TABLE I.—*Continued*

Item	Average 1955–56	1956–57
Aerators:		
Mixed liquor susp. solids (ppm)	2,200	2,320
Sludge index	34	33
Air used (cu ft/gal)	0.7	0.6
Kilowatt hours per million gal	411	421
Returned sludge (%)	21	22
Primary sludge:		
Solids (%)	4.9	5.0
Volatile solids (%)	58	57
Solids removed, dry (lb/mg)	1,413	1,401
Volume (gal/mg)	3,217	3,475
Digested sludge:		
Solids (%)	9.7	9.2
Volatile solids (%)	41	47
pH	7.0	7.0
Alkalinity (ppm)	2,600	2,600
Dry sludge removed (cu yd)	7,255	9,530
Gas production:		
Total (1,000 cu ft)	16,474	17,950
Gas per pound volatile solids (cu ft)	10.9	13.2
Cost data ($):		
Cost of operation	93,733.88	105,253.73
Revenue bonds (retirement and interest)	37,340.75	308.67
Collection (billings, etc.)	18,647.68	20,412.81
New equipment	4,493.46	8,611.46
Lift stations and sewer maintenance	40,715.23	68,010.79
Insurance	740.93	301.80
Taxes (contribution in lieu of)	18,000.00	18,000.00
Depreciation	—	30,732.00
Total	213,671.93	251,631.26
Cost per mil gal (fixed charges included)	53.55	66.53
Cost per mil gal (less fixed charges)	27.91	35.59

September 1956 disclosed that some raw sewage reaches the river during peak sewage flows.

Changes in the trunk sewers and diversion chambers will be required for correction of the problem. Primary treatment facilities will need to be enlarged, possibly doubled, in order to provide treatment for a greater portion of the storm-water flow. Complete treatment must be available for all of the dry weather flow and partial treatment for 40 to 45 mgd of storm flow. To this end consulting engineers have been retained to prepare a report on the future course of plant expansion.

Table I summarizes the operation data for the fiscal years 1955–56 and 1956–57.

Annual Report of the Boise, Idaho, Sewage Treatment Plant for the Years 1956 and 1957 *

A. J. WAHL, *Superintendent*

The Boise, Idaho, activated sludge plant has operated satisfactorily since its completion in 1950. The plant has a design capacity of 9 mgd. In 1957 the average flow was 7.4 mgd. Summer flows approach twice the winter flows because of high ground water infiltration. July pumpage averaged

* For last previous report see THIS JOURNAL, **29**, 3, 318 (Mar. 1957).

TABLE II.—Summary of Operating Data at the Boise, Idaho, Sewage Treatment Plant For 1956 and 1957

Item	Average 1956	Average 1957
Connected population, est.	28,256	28,400
Population equivalent, est.	36,456	36,600
Sewage flow (mgd)	7.0	7.4
Suspended solids:		
Plant influent (ppm)	150	160
Clarifier effluent (ppm)	70	70
Final effluent (ppm)	8	10
Removal (%)	95	94
BOD, 5-day:		
Plant influent (ppm)	110	100
Clarifier effluent (ppm)	90	75
Final effluent (ppm)	8	5
Reduction (%)	93	95
Aeration tank data:		
Aer. period (hr)	7.7	7.3
Air supplied (cu ft/gal)	0.84	0.79
Mix. liq. susp. sol. (ppm)	1,050	1,150
DO (ppm)	2.7	2.4
Sludge susp. sol. (ppm)	3,600	3,600
DO, final effluent (ppm)	5.8	5.8
Chlorine applied (ppm)	1.1*	1.1
Sludge digestion, data:		
Sludge to dig. (gal/day)	51,000	53,000
Temp. (°F)	90	90
pH	6.9	6.8
Sludge gas data:		
Gas produced (cu ft/day)	56,000	56,000
Cu ft/lb dry solids	7.3	6.7
Operating cost ($):		
Total	55,754.71	61,378.44
Per mgd	21.76	22.80

* Based on nine months of operation.

9.6 mgd compared to the January flow of 4.9 mgd. Close control of the treatment process is maintained through application of laboratory findings. A daily record of sewage flow, BOD, suspended solids, chlorine residual, sludge pumping, gas production, and equipment operation is maintained. A summary of operating data for the past two years appears in Table II.

Once in the fall and again in February a mass of floating sludge accumulates in the secondary clarifier inlet wells. The sludge originates in the aeration tanks. The cause of this condition is unknown and laboratory tests reveal nothing unusual. In an attempt to correct the problem aeration tanks are by-passed for 24 hr, then both the air supply and return sludge rate are increased. It takes a week to 10 days for the sludge to disappear.

For the past two years experimentation with sludge thickening has been carried on and one of the three primary clarifiers was used for this purpose. Sludge was continuously pumped from the other two clarifiers at a rate of 92 gpm and chlorine was added. Only partial success was obtained, as the solids content increased from 1.7 to 2.5 per cent. Further testing with different equipment is planned.

Sewer Maintenance

Since 1952 a preventive maintenance program has been carried on at a cost of approximately $11,000 per year. A steady decrease in the number of sewer stoppages has resulted. In 1956 stoppages totaled only 58 compared with 158 in 1952. Stoppages in private sewers remained substantially unchanged during this same period.

Public Relations

The treatment plant is within 1,000 ft of about 50 residents. Odor complaints were very few (three in 1957), all attributed to the sludge beds. Nevertheless, everything possible is done to avoid conditions that cause complaints. Plant grounds are continually improved and beautified. Screening of the plant with trees has been carried out in cooperation with the park department. Employees issue a quarterly pamphlet called "Sewage Gas."

Report of the Racine, Wis., Sewage Treatment Plant for 1957 *

THOMAS T. HAY, *Superintendent*

In 1957 voluntary certification of sewage treatment plant operators was begun and 11 employees were certified. Prior to certification the in-service training school at the plant was accredited. High plant efficiency is at-

* For last previous extract see THIS JOURNAL, **29**, 9, 1075 (Sept. 1957).

TABLE III.—Labor Time Required for Unit Operations at Racine, Wis., for Three-Year Period, 1955–57

Unit Operation	Per Cent of Total Time
Administration and laboratory	15
Digesters	15
Building maintenance	15
Lift stations	14
Clarifiers	13
Equipment maintenance	8
Drying beds	5
Grit removal	5
Grounds maintenance	5
Sewers	3
Chlorination, comminutors, misc.	2

tributed to the unusual interest shown by operating personnel. Table III shows a breakdown of plant labor time for the three-year period 1955–57. Approximately 33,000 man-hours of labor are expended annually for plant operation.

Plant operation for 1957 was normal, although some difficulty was experienced in handling the waste from a tannery. By July the three primary digestion units had accumulated so much hair that draining became necessary. Cleaning of the primary digesters was required in 1956 also. An attempt is being made by the tannery to develop a satisfactory scheme for hair removal.

Operation data are summarized in Table IV and show only slight variation from the previous year.

TABLE IV.—Summary of 1957 Operation Data at the Racine, Wis., Sewage Treatment Plant

Item	Average
Total rainfall (in.)	31.65
Population:	
Connected	86,000
Equiv., BOD	106,300
Equiv., susp. sol.	101,300
Sewage flow (mgd)	15.0
Per cap. sewage flow (gal)	173
Total solids:	
Influent (ppm)	715
Effluent (ppm)	585
Reduction (%)	18
Settleable solids:	
Influent (ml per liter)	4.3
Effluent (ml per liter)	0.2
Reduction (%)	95
pH:	
Influent	7.7
Effluent	7.7
Suspended solids:	
Influent (ppm)	185
Effluent (ppm)	75
Reduction (%)	60
BOD, 5-day:	
Influent (ppm)	140
Effluent (ppm)	80
Reduction (%)	43
Chlorine demand:	
Raw (ppm)	6.5
Effluent (ppm)	6.3
Raw sludge to digesters:	
Gal per day	29,764
Dry solids (%)	7.8
Dry solids (lb per day)	19,805
Volatile solids (%)	51
pH	6.8
Digested sludge:	
Digested solids to beds (lb per day)	3,227
Per cent solids	13.2
Volatile solids (%)	35
pH	7.1
Analysis of dry sludge (%):	
N	1.4
P_2O_5	2.6
K_2O	0.3
Grease	3.9
Humus	34
Moisture	15
Gas, cu ft per capita per day	0.7
Gas, cu ft per lb vol	5.9
Operating costs ($):	
Total	121,595.53
Per capita	1.41
Per mil gal	22.37

Annual Report of the Greater Winnipeg (Man.) Sanitary District for 1956 *

N. S. Bubbis, *General Manager*

The Greater Winnipeg Sanitary District made steady progress during 1956 on reducing the amount of pollution going into the rivers flowing through the District. At the end of 1956 approximately 86 per cent of the

* For last previous extract see This Journal, **29**, 7, 826 (July 1957).

sewage flow and 90 per cent of the pollution contributed by the 10 municipalities in the District received treatment at the District plant. With the completion of pumping stations and interceptor connections, to serve two additional areas, the amount of sewage treated will be increased to 92 per cent of the flow and 94 per cent of the pollution.

Rapid extension and development of both industrial and residential areas in all the municipalities served by the District has necessitated considerable extension of the municipal sewer systems. In addition, two areas made application to join the District.

A record snowfall of 99.5 in. created a serious flood threat. Fortunately, weather conditions attenuated the danger. The river stage was the highest since the 1950 flood, and was handled successfully by the pumping stations of the Greater Winnipeg Dyking Board. The District has the responsibility of maintaining and operating flood pumping stations.

Plant Operation

Operation of the enlarged plant was satisfactory throughout the year. Equipment maintenance and painting were carried out as required. A total of 22 comminutors was changed and a number of combs and teeth were replaced.

One digester was cleaned and the clarifiers were inspected. Elutriation with fresh water is to be tried, and a water line was installed to supplant the effluent water line used previously. A new 20- by 71-ft greenhouse was erected to replace the existing structure.

Disintegrated concrete walls and columns above the spring line in the discharge chamber had been repaired in 1951 with a ½-in. coat of cement plaster. After five years the plaster had almost completely disappeared from a large area. On close inspection it was apparent that an inadequate bond had been developed between the original concrete and the plaster coat.

Repair was made by driving ¼-in. stud anchors 1 ft on centers into the concrete. Expanded metal laths were bolted to the anchors. Two coats of cement plaster * were applied, making a total thickness of approximately 1 in. It is believed that this anchored coat will stay in place and protect the original concrete.

Industrial Wastes

The campaign to control industrial wastes continued at an increased pace. More than 100 investigations were made at 22 industries. Approximately 1,350 hr were spent in sampling, and some 114 analyses were made. Also, 570 samples were analyzed by the various industries and the results were reported to the District. A thorough review also was made of water exemptions in order to adjust service charges.

Odors coming from industrial wastes discharged to the sewers were a continuing problem. A two-fold campaign was undertaken. First the industries were urged to modify operations to reduce the odor problem. Second, various odor-masking chemicals were tested.

Coil Filter Tests

A 10-ft by 10-ft coil filter and ancillary equipment were installed. The sludge to be filtered varies considerably, and during certain periods contains a high percentage of silt which is difficult to filter.

During the first test period ferric chloride was the only coagulant used. The percentage used was 6.8 per cent on a dry weight basis. This proved too costly, since ferric chloride costs $0.08 per pound. Lime was tried and the ferric chloride dosage was reduced to 2.7 per cent. A 10 per cent lime

* Ciment Fondu.

TABLE V.—Summary of Operating Data, Greater Winnipeg Sanitary District, for 1956 *

Item	Average
Population served	392,300
Precipitation (in.)	23.77
Sewage flow (mgd)	27.1
Grit (cu ft/mg)	1.9
Settleable solids:	
Plant infl. (ml/l)	6.0
Clarifier effl. (ml/l)	1.4
Removal (%)	74.8
Suspended solids:	
Plant infl. (ppm)	339
Clarifier effl. (ppm)	127
Removal (%)	59.3
BOD:	
Plant infl. (ppm)	295
Clarifier effl. (ppm)	162
Removal (%)	44.4
Sludge gas:	
Total (mil cu ft)	133.70
Used (mil cu ft)	78.34
Wasted (mil cu ft)	55.36
Methane (%)	67
Sludge digestion:†	
Raw sludge:	
pH	5.9
Moisture (%)	88.8
Volatile (%)	63.5
Digested sludge:	
pH	7.5
Moisture (%)	92.1
Volatile (%)	48.9
Temp. supernatant (°F)	90
Sludge lagoons:	
Dig. sl. pumped, dry solids (lb)	497,100
Sludge removed, dry solids (lb)	0
Elutriation:‡	
Days operated	183
Sludge treated (gal/mo.)	23,130
Wash water (gal/mo.)	1,682,580
Alkalinity, elut. sl. (ppm)	848
pH	7.5
Moisture (%)	89.6
Volatile solids (%)	48.3
Filtration:‡	
Days operated	110
Wet solids (ton)	2,478
Dry solids (ton)	750
Cake moisture (%)	70.7
Ferric chloride (%)	2.5
Lime (%)	8.9
Filter rate (lb/sq ft/hr) (Range, 2.2–7.5)	4.6
Cost of operation ($):	
Administration and debt	145,059.44
Collection	87,995.84
Treatment	158,926.33
Total	391,981.61

* All flows and capacities in U. S. gallons.

† Digesters Nos. 1, 2, 3, 4, and 7 are used as secondary units; digesters Nos. 5 and 6 are primary units.

‡ The coil filter was operated on a test basis only; there was no filtration or elutriation during June and July, and no filtration in January.

dosage was used. Production averaged 3 psf/hr.

A comparison of costs using ferric chloride alone and lime with ferric chloride showed a saving (using the latter) of $5.09 per ton of solids on a dry weight basis.

Further tests improved the production of cake to about 4 to 4.5 psf/hr with a moisture content of 70 to 72 per cent by weight. Sag of the coils was noted, and the filter could not be operated. An analysis indicated that about half of the embedded material in the spring coils was carbonate.

Examination by the manufacturer resulted in replacement of the coil springs. The original coils had an elliptical cross section instead of the usual "home-plate" cross section. The "home-plate" coils were supplied as replacements. Operation of the filter under supervision of a chemist from the manufacturer produced good results. Filter rates varied from 7.5 to 4.6 psf/hr, depending on the character of the sludge.

A gradual build-up of material in the coils caused them to sag some. Further investigation is indicated to determine the cause of the build-up. The cause may be due to the use of lime, the silt content of the sludge, or the fairly high salt content in the well water used for spraying and washing the coils. The well water may contain excessive lime.

A summary of the operating data for 1956 is given in Table V.

REPORT ON A RELINED SEWER

By W. E. McFee

Supervisor, Product Information Service, Armco Drainage and Metal Products, Inc., Middletown, Ohio

Almost thirty years ago the sewage treatment plant of the North Shore Sanitary District, Waukegan, Ill., was constructed. It was built to serve the city of North Chicago and nearby industries. As a part of this project, a section of a ravine was filled in to allow greater use of the site. Approximately 300 ft of 48-in. diameter rigid type sewer was installed to carry the ravine storm water and local industrial wastes to Lake Michigan. This structure served adequately for many years. But in 1942 it became evident that industrial wastes were causing deterioration of the structure. By 1945 the invert was gone and partial structural failure of the crown resulted.

Since the fill over the original structure ranged from 15 to 20 ft, it appeared impractical to replace the conduit by the open-cut method. To solve the problem the North Shore Sanitation District decided to thread 42-in. diameter asbestos-bonded coated and paved pipe through the original 48-in. line. The new pipe was fitted with internal expanding coupling bands. Angles were welded to the pipe at the third points to provide runners for sliding the pipe and to keep it centered in the old structure. The space between the old and new pipe was grouted. Rehabilitation work was completed in 1946.

Inspections made since 1946 indicate that the asbestos-bonded pipe is performing very satisfactorily. The interior of the pipe is in good condition today (Figure 1). During inspections

FIGURE 1.—Asbestos-bonded sewer after 12 years of service.

fumes were so pungent that entrance into an unventilated manhole was impossible without the use of gas masks. The pH of effluent samples collected during the period 1946–56 ranged from a low of 0.6 to a high of 10.9. Temperature varied from 51 to 96°F.

In 1956 secondary treatment was added to the North Chicago treatment plant. In order to provide an area for the new facilities, it was necessary to extend the sewer farther down the ravine. Approximately 500 ft of 48-in. asbestos-bonded sewer was used in the extension to a new outlet at the lake shore.

TIPS AND QUIPS

Radioactive Waste Disposal Progress

The General Electric Company technical staff at the Hanford Atomic Works (Washington) has reported the use of an aluminum silicate gel to contain radioactive wastes. In comparison with the heavy vaults now used for burying high-level reactor wastes, the cost involved with the use of the silicate gel is reported to be attractive. One of the reasons for this is the fact that at Hanford a source of the aluminum used is from the liquid wastes of one of the plant processes.

Constant Voltage

A self-regulating distribution transformer which adjusts its turns ratio to maintain a constant output voltage has been developed. It changes taps in the primary whenever load changes cause output to deviate 2.5 per cent from rated 120 or 240 v. Band width of control is about 3.5 v. Ratings of units initially produced will be confined to a range of from 10 to 100 kva at voltages of from 2,400 to 14,400. For information write to Line Material Industries, McGraw-Edison Co., Milwaukee 1, Wis.

Do It Yourself, Next??

By mounting a standard army litter on a lightweight frame with two wheels, one person can do the work of two or more stretcher bearers.

What's in a Name

From action taken at the 1958 annual meeting of the Virginia Industrial Wastes and Sewage Works Association it is apparent that the saying, "Sticks and stones will break my bones but names will never hurt me," is just so many words. At any rate a change-the-name-of-the-Association contest, with a cash prize of $25, has been authorized. To Virginians the word "sewage" needs a little "masking."

An anonymous member of the Association, who supports the view that the Association's name "stinks," has donated an additional $25 to the cause.

Contestants must be paid-up members of the Virginia Association.

Reclaimed Waste

At the Torrance, Calif., butadiene plant of the Shell Chemical Corporation the problem was to find an additional 600 gpm of boiler feed water.* Engineers decided to make use of a waste stream of steam condensate which had been discharging to the plant sewer. The condensate contained 40 ppm of oil and was at a temperature of 130°F.

An economic evaluation showed that less expense would be required to install a 600-gpm filter unit to treat the waste stream than to treat water from another source. Operating costs of the filter were also calculated to be lower.

* *Power Industry*, 74, 7, 9 (July 1958).

When You Travel in Florida

When you travel in Florida keep an eye open for Florida SIWA members. To spot them, look for the blue and gold decals attached to automobiles belonging to Florida members (Figure 1).

FIGURE 1.—Decal of the Florida Sewage and Industrial Wastes Association.

In case your Member Association is interested in obtaining further information, we note the Florida decals were manufactured by The Palm Brothers Decalcomania Co., with offices in New York, Cincinnati, and Chicago.

Decals

Today's modern treatment plant requires its equipment to be clearly and uniformly marked for ease of servicing. Packaged kits of decals, with appropriate markings for preventive maintenance and lubrication schedules, are now available. The kits were designed primarily for industrial plants but most markings would be suitable for use in treatment plants. It is reported the markings are not affected by prolonged contact with moisture. The preventive maintenance kit contains 474 pieces, assorted over 59 different equipment names, and sells for $49.50. The lubrication kit contains 4,276 markings, including 1,000 nameplate decals, and sells for $75.00. Refills for both kits are available. A brochure and additional information can be obtained from The Meyercord Co., 5323 W. Lake St., Chicago 44, Ill.

Pittsburgh's Blue Chimney

In the May 1958 issue of the JOURNAL TIPS AND QUIPS reported on how the Allegheny County Sanitary Authority (Pittsburgh, Pa.) proposes to take its sewage 80 to 100 ft underground. Now, we report on how a part of that sewage is to be taken above ground.

Appearing as part of the Pittsburgh skyline is the blue chimney of the Sanitary Authority. At last word the chimney was 130 ft high and growing at the rate of 4 ft per day. The completed stack will be 300 ft high.

We assume, of course, that the face bricks are JOURNAL "blue." In the interest of economy, however, we suggest that no attempt be made to change to JOURNAL "yellow" every September.

Sewer Service Charges

In the April 1958 issue of *Western City*, sewer service charges used in 80 western cities are analyzed. Extensive footnotes accompany the article. The fact that the survey was limited to the states of the far west in no way lessens its value to interested readers in other areas.

Waste Utilization

It is reported that frost heave in the beds of roads and railroads is largely overcome by injecting lignosulfates from spent sulfite liquor into the soil. Thus, better highways result from the utilization of a troublesome waste product.

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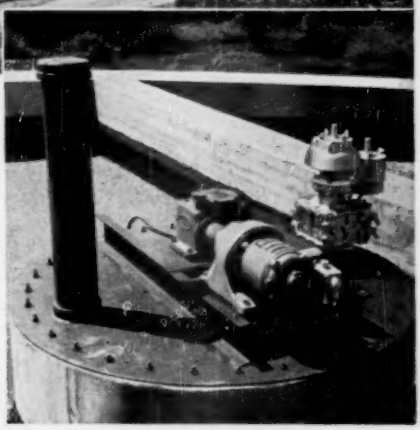
FIG. No. 5800C



"VAREC" Fig. No. 5800C
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Proceedings of Member Associations

CENTRAL STATES SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

The 31st Annual Meeting of the Central States Sewage and Industrial Wastes Association was held at Purdue University, Lafayette, Ind., May 5–7, 1958, with technical sessions combined with the 13th Purdue Industrial Waste Conference.

At the Annual Meeting the Indiana membership petitioned for the withdrawal of Indiana from the four-state group. It was decided to submit the issue to the Association membership by mail ballot on the constitutional changes necessary.

FSIWA President, Kenneth S. Watson, brought the greetings of the Federation and presented the Arthur Sidney Bedell Award (in absentia) to O. J. Muegge, Wisconsin State Sanitary Engineer, Madison, Wis., and the William D. Hatfield Award to R. A. Kronewitter, Superintendent, Sewage Treatment Plant, Mishawaka, Ind.

Officers elected were:

President: R. W. Frazier, Oshkosh, Wis.

1st Vice-President: L. H. Smith, Minneapolis, Minn.

2nd Vice-President: P. L. Brunner, Fort Wayne, Ind.

3rd Vice-President: W. A. Sperry, Aurora, Ill.

Secretary-Treasurer: Scott E. Linsley, St. Paul, Minn.

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(*Continued on page 468a*)

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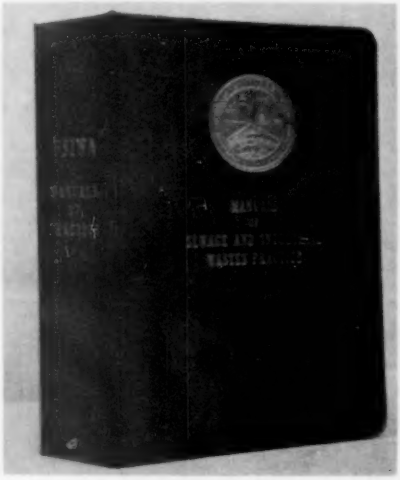

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MARYLAND–DELAWARE WATER AND SEWAGE ASSOCIATION

The 31st Annual Conference of the Maryland-Delaware Water and Sewage Association was held at the Francis Scott Key Hotel, Frederick, Md., on June 12–13, 1958. Registration totaled approximately 210.

Papers of particular interest to sewage works personnel included:

"Waste Yields Profits to Industry," by James O. McCanner, and Carroll Etchison, Everedy Co.

"Water Contamination by Refuse Disposal," by Charles W. Snyder, Public Health Engineer, Maryland State Department of Health.

"Waste Abatement Program on the North Branch of the Potomac River," by Richard Hazen, Hazen and Sawyer, Consulting Engineers, New York, N. Y.

"Tidewater Refinery Waste Problems," by A. W. Lewis, Superintendent of Technology, Tidewater Oil Company.

The program also included a panel discussion on "Increasing Sludge Digester Capacity," moderated by Ralph E. Fuhrman, FSIWA Executive Secretary. Participating were Thomas Forrest of the Chicago Pump Company, Thomas J. McCormack, Pacific Flush Tank Company, and B. F. Rockecharlie, Dorr-Oliver, Inc.

The following officers were elected:

President: D. K. Harmeson, Dover, Del.

1st Vice-President: Louis E. Otts, Jr., Riverdale, Md.

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(Continued through page 476a)

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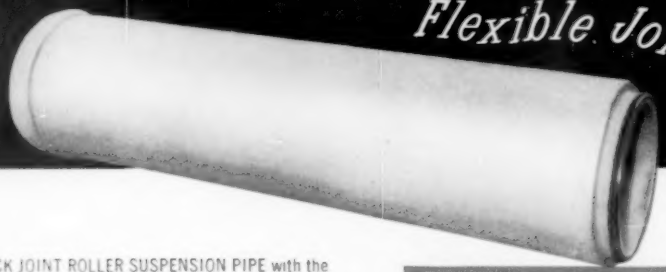

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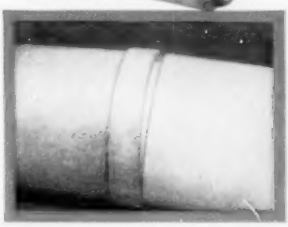

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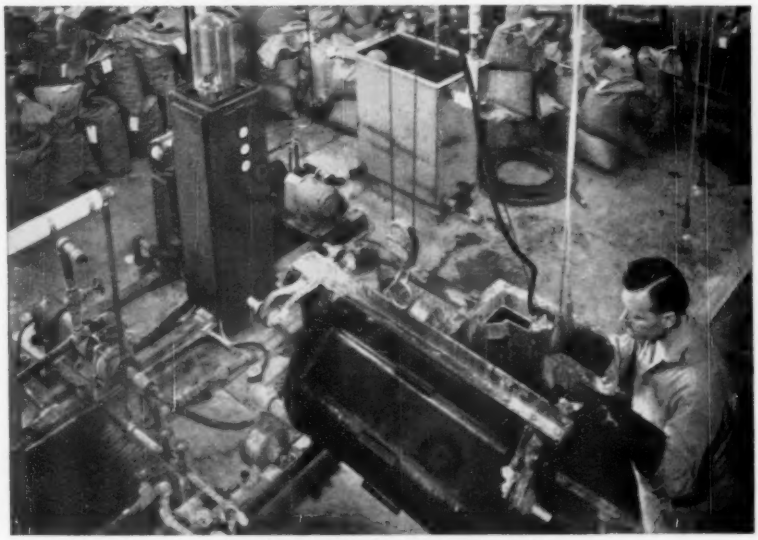

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